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ABSTRACT

This report examines the potential impact of optical media--videodiscs, compact audio discs, and optical disks, tapes, and cards--in library related applications. A detailed consideration of the technology includes discussion of the underlying principles, the various forms in which the technology is marketed, production methods and costs, and the capabilities of each different medium. An introductory chapter outlines the different forms of optical media and their potential applications in libraries. Each of the remaining 11 chapters then addresses the details of one of the following technologies: videodiscs; interactive videodiscs; recording digital data on videodisc; videodisc production; compact audio discs and CD ROM (compact disc read only memory); videodiscs and CD ROM as digital publishing media; optical digital discs; optical digital products; and erasable optical media. A number of video and compact audio disc projects currently being developed or investigated in library settings are examined in the appropriate chapters, including audio and video applications at Video Patsearch, the National Library of Canada, the National Library of Medicine, and the Library of Congress; digital data publishing projects at MiniMARC, Information Access Corporation, Carrollton Press, the Library Corporation, and other companies; and library applications of optical digital disk technology at the Library of Congress, the National Library of Medicine, the National Air and Space Museum, the Public Archives of Canada, and Disclosure Information Group. An appendix explains the process of converting text, graphics, and audio to digital form. (THC)

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VIDEODISC AND OPTICAL DIGITAL DISK TECHNOLOGIES AND THEIR APPLICATIONS IN LIBRARIES

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Council on Library Resources

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INTRODUCTION

Information Systems Consultants, Inc. of Bethesda, MD was retained by the Council on Library Resources to study videodisc and optical digital disk technologies and their current and future place in libraries. The study was to place particular emphasis on aspects of the use of the technologies for the preservation of library materials.

The experience of preparing this report has been a frustrating one. While the literature is replete with references to the promise of optical technologies for library and information applications, products and systems to support such applications are rare outside of laboratory settings or large scale custom applications. Claims that the optical media will be the technology of the 1980s and 1990s in education, information storage and retrieval, distribution and storage of online data bases, archival management and digital data storage are far from being realized.

That most of the prototype optical systems have emerged in library-reported information storage and dissemination environments provides little comfort. This market is unlikely to provide sufficient critical mass to serve as the launching pad from which the technologies can gain a firm foothold. The library market is too small, even if assessed in terms of several hundred million dollars. No matter how great the potential contribution of the optical technologies for library, archives, and records management applications, the promise will not be fulfilled unless the media become widely available commercially.

By the beginning of 1985, only two of the optical media--reflective optical videodiscs and compact audio discs--appeared to have achieved such commercial viability. And this was limited to "standard," read-only applications: video and

audio programming respectively. There was also evidence to suggest that the media's potential for digital data publishing was about to be tested in operational, commercial applications.

The situation was less clearly defined for optical digital disks, the write once-read medium being promoted as a computer mass storage device. Sources of supply and markets for "smaller" 1GB capacity media were emerging. However, penetration of the mass storage 4GB disk was flagging, a disturbing fact as many of the expectations of the impact of the optical disk medium libraries are based on the performance of these larger systems.

The primary concern of this report is to examine the potential impact of the optical media in library related applications. This cannot be assessed without detailed consideration of the technology: the underlying principles, the various forms in which the technology is being marketed, production methods and costs, and the capabilities of each different medium. After an introductory chapter outlining the different forms of optical media and their potential for application in libraries, the bulk of the report addresses the details of the technologies. Specific products and projects aimed at the library market are detailed in the final chapters.

Much of the potential for library applications is based on the media's ability to store digitized image and audio data, and machine-readable coded digital data. Methods of converting text and audio to digital form are described in the Appendix.

CHAPTER 1. OVERVIEW OF THE OPTICAL MEDIA AND THEIR POTENTIAL APPLICATIONS IN LIBRARIES AND RELATED INSTITUTIONS

Videodiscs, compact audio discs, CD ROM, and optical disks, tapes, and cards share "optical" characteristics in that the dominant technologies in each medium rely on the use of optically sensitive materials to store information. Most also use light, generally in the form of lasers, for both recording and reading.

The materials and processes underlying each medium are remarkably similar; the differences among the media arise from the ways in which they are developed and marketed for commercial applications. Herein lies much potential for confusion; a confusion which shows little sign of abating as companies which have expended billions of dollars in developing the technology continue to reshape their product lines in search of what is proving to be an elusive market.

This continued product development and the tardiness of the market to adopt the products offered, ensures that any discussion of the technologies is necessarily tentative. It is not possible to make categorical statements about the cababilities of the various media as these are continually being changed. Nor is it possible to be dogmatic about the cost or benefits of specific applications as the limited market penetration of the media hinders assessment of cost and performance based on operational systems.

THE OPTICAL MEDIA

By the end of 1984, four types of optical media were being promoted in North America. The videodisc, the first optical medium to be commercially marketed, was the most firmly established. Of several competing videodisc technologies, the reflective optical videodisc was clearly dominant and

commercial support for the alternative videodisc technologies had virtually disappeared. Videodiscs were established in two applications: as a publishing and distribution medium for general purpose "entertainment" programs such as motion pictures, and as the vehicle for interactive programs for training, education, arcade games, public information and marketing. Although some services and products were available to support the production of single or limited run videodiscs, the dominant use of the technology was in applications which require the mass replication of many copies of the program.

The distinguishing characteristic of videodisc is that all information is recorded within the audio and video format of a standard television signal. This does not mean that the medium is limited to the reproduction of only moving images and sound; techniques have been developed to accommodate still images and to handle the storage and replication of digital data within the video format. All types of information--motion and still video, audio and digital--may be mixed on a single disc, or a disc may be devoted to only one type of data. Applications which combine audio and video programming were the most firmly established and programming that mixes audio, video, and digital data on a single disc was becoming commonplace. The least common applications were those in which a videodisc is devoted entirely to digital data.

Although a relatively new product release, the compact audio disc appears to have sufficient commercial backing and consumer appeal to guarantee viability in its primary application--sound recording. As with videodiscs, one form of the technology appears dominant: that which relies on lasers for recording and reading.

The technology for recording and playing compact audio discs is very similar to that for reflective optical videodiscs; so similar that the same facilities can be used for

mastering and replicating both video and compact audio discs, and several manufacturers are marketing players that will handle both media. The major difference is in the nature of the signal recorded on each medium. The compact audio disc is designed to carry digital data, the videodisc accommodates information in the analog video format. Like the videodisc, the compact audio disc is being promoted primarily--in fact, as of late 1984, solely--as a mass replication technology.

Any type of digital data may be mastered and replicated on a compact disc. The name compact audio disc is generally reserved for discs which carry digitized audio. Applications in which the compact disc is encoded with machine-readable digital data are beginning to emerge. Such discs may be described by several names, including compact disc read-only memory (CD ROM) and optical read-only memory (OROM). Although the associated CD ROM drives or players were not available in commercial quantities by the end of 1984, there was a considerable amount of interest in this use of the media, and it appears likely to become established during 1985.

The future of the group of media known as optical digital data storage devices is more problematic. Most commonly discussed as a disk format, but also being developed in tape and card formats, these media again share common technological foundations with the video and compact disc media. The essential difference is again one of the targeted market and the consequent direction of commercial development. Most work on the optical digital disk has been directed toward the computer mass storage market; toward development as a computer storage peripheral capable of taking its place--or, in some scenarios, replacing--the traditional magnetic disk and tape media. Success in this market is dependent upon the storage medium being able to record data at the user site; of being as easily written as read. This is in marked contrast with the direc-

tion of product developments for the optical media discussed up to this point. Videodisc, compact audio disc, and CD ROM emphasize mass replication and read-only applications; the optical digital media stress write once and read capabilities --also called DRAW or direct-read-after-write.

Write once and multiple read capabilities do not result in media which mirror the qualities of magnetic disk and tape. The magnetic media are erasable and thus provide multiple write capabilities. Many companies are attempting to engineer erasability into optical digital media. To date, these attempts have not resulted in anything more tangible than prototype systems and tentative product announcements.

Market penetration of the optical digital media has been disappointing. In North America, the media cannot yet be regarded as established, and it was only in the second half of 1984 that deliverable systems became a reality. Most of the usage appears to be experimental, and such usage as there is, is far below the levels projected by most industry analysts.

As detailed in chapters 11 and 12, the library and information communities are at the forefront of testing the various optical media--videodisc, CD ROM, and optical digital disk--in digital data publishing and storage applications.

POTENTIAL LIBRARY AND INFORMATION APPLICATIONS OF THE OPTICAL MEDIA

Ever since the optical media began to emerge from the laboratory in the early seventies, reams have been written about the promise of the technology for library, information center, archive and publishing applications. Despite the passage of time, it is not yet possible to assess the validity of the projections; maturation of the technology has been much slower than anticipated. Products based on the technologies are but recent evolutions, and pilot projects to test their

performance in "live" situations are still in progress. Those products and projects of particular significance to libraries are described in chapters 11 and 12. It is too early to make accurate forecasts on the viability of the media in general, or information related applications in particular.

It is, however, possible to examine the potential impact of the media on libraries, archives, data base services, publishers and related organizations. That impact falls into two major areas, both integral to basic functions of information oriented enterprises. These areas of major impact can be simplistically categorized as access and preservation.

At the most direct level, the emergence of new forms of media require an expansion of the responsibilities of libraries, archives and other repositories to collect, store and provide access to the materials of relevance produced on such media. Public libraries are already expanding their collections to encompass motion picture programming on videodisc and sound recordings on compact audio disc, and academic and special libraries are also being called upon to provide access to interactive videodisc programs for education and training. If videodiscs and CD ROM become acceptable media for software and data base publishing, these too will need to be accommodated. Of potential special interest for the collecting activities of many libraries and archives are applications which use the videodisc as the publishing medium for image data bases: large files of still images which can be readily accessed and retrieved for use by patrons.

At the next level of sophistication, the videodisc and compact audio disc offer preservation and access opportunities for video and audio materials currently published in other formats. Examples of such usage of the technologies are becoming common: the National Air and Space Museum videodisc collection of photographs of the history of aviation and the

Library of Congress' compact audio disc of music performances from its collection and its videodisc transfer of motion picture footage previously available only as paper prints. The preservation motif in such projects has two aspects: the direct preservation of materials which are at risk in their original medium of publication, and the indirect preservation advantages of reducing daily wear and tear on the original materials by diverting a significant percentage of usage to the disc-based reproductions.

Access benefits are also clear, but differ with the extent to which the alternate media are made widely available. Policies on distribution are often determined by factors other than economics and interest; many institutions are restricted by copyright and donation agreements in the extent to which they make such materials widely available. If unfettered by such limitations, an institution may choose to distribute such publications widely. In other circumstances, the availability of multiple copies of the material on disc only for use in-house can still bring access benefits. Materials can be made available in several locations, more than one user can access an item at the same time, and unrestricted access can be provided to materials which would otherwise require special security precautions, complicated equipment, or specially trained staff.

Although videodisc production costs are falling, it is not yet clear whether the costs of small runs of high quality video and compact audio discs will justify use of the medium for only limited quantity replication. It can be expected that cost justification decisions will depend upon the perceived value of the expected benefits, and this value will not necessarily be expressed in monetary terms.

However, it is in the various digital applications of the media that the most far-reaching effects are expected. Dif-

ferent technologies are associated with different applications, each of which has varying access and preservation implications. All three of the optical media most widely promoted for digital data storage--videodisc, CD ROM and optical digital disk--are regarded as being suitable for the storage of any form of digital data: machine-readable character encoded data and digitized audio and image data. However, compact audio disc is generally regarded as the appropriate medium for the storage of digitized audio data, and most commentators appear to consider the optical digital disk as the appropriate medium for the storage of digitized image data. Videodisc and CD ROM are currently the media of choice for the publication of machine-searchable character encoded digital data. As yet, it is not clear whether either medium offers significant advantages over the other in mass replication applications such as the distribution of software, bibliographic data, and full text. Videodisc does enjoy an advantage when an application includes a mix of digital data and analog video or image data, and it currently offers a greater storage capacity than CD ROM.

The preservation aspects of digital data publishing on optical media are less impressive than is the case with other uses of the technologies. Certainly, the media appear to offer significantly greater durability and longevity than the floppy disks and magnetic tape now used in digital data publishing/ distribution. This, combined with their storage capacity and random access capabilities may result in the "publication" of material that was previously only readily available online. The probable publication pattern of discs encoded with data such as machine-readable bibliographic files--the regular distribution of new, cumulative discs--will provide "snapshots" of such files at specific intervals, facilitating the retention of this data for future analysis

and research. At present, the maintenance of such an archival record is a tedious and expensive process, usually undertaken only by data base services or data base suppliers and retained by them only for limited periods.

The potential for improved access provided by the optical media when used for digital data publishing is much greater. An obvious application is for the publication of files currently available online through large computer systems which can only be accessed onsite or through increasingly expensive telecommunications channels. The economics of the media and its ability to give data base producers access to users without the mediation of a data base service may also afford new opportunities for smaller data base producers--alone, or in cooperation with [illegible]. Systems which combine abstracting and indexing information with the full text of the items cited may also be feasible, as may the mix of machine-readable indexing data with digitized facsimile images of the items described.

As discussed in the preceeding pages, the potential of the media for the publication and distribution of photographic archives and digital data appears to be considerable. However, the applications receiving the most attention are those which utilize the write once optical digital disk for the storage of digitized document images and machine-readable digital data. Conceptually, there is no reason why digital disks "mastered" with such data cannot be replicated in quantity; indeed, at least one manufacturer of write once systems mentions this possibility in its product literature. For the time being, this is not being widely discussed; rather, the focus of the work in this area is on testing the practicality of the applications and assessing the performance of the technology.

Preservation and access appear to be equally significant as motivating forces behind this work. Projects which focus directly on the preservation of records of historical value are being sponsored by major archives. The initial work is directed towards the archival storage of machine-readable data which is currently recorded on magnetic tape. The expected advantages of the optical digital disk in this application include greater durability, longer storage life, and more compact storage.

The expectations driving applications in which the disk is used as the storage medium for the digitized images of documents vary. For commercial organizations, access is a prime motivation. The technology's ability to reduce large paper and microfiche files to a single compact form, readily and rapidly accessible from multiple local or remote workstations is attractive to certain types of enterprises, as is the fact that such systems entail no manual refiling and do involve one-at-a-time limitations on use.

Similar rationales also apply to such applications in library and archival settings. However, in these environments, there is a greater awareness of long-term preservation and storage considerations. These include the advantages outlined for the videodisc and CD ROM publication of materials available in other formats: reduced handling of fragile originals and, in extreme circumstances, capture of the information and image content of materials which are disintegrating in their original format. The approach is also receiving attention because of its potential to reduce the physical space requirements of very large libraries and archives.

Such are the hopes and dreams guiding the emerging applications of optical digital media in libraries and other information settings. The future of these applications will be determined by performance and economics.

However, like the technologies which have preceded them, the optical media are not panaceas. Their successful implementation will demand changes in emphasis. For instance, it is exciting to be able to store the digitized images of hundreds of thousands of pages of published materials on a single, rapid, user-friendly, online retrieval system. However, such capabilities will be worthless, unless accompanied by adequate location guides: comprehensive, high quality, easily used abstracting and indexing tools.

CHAPTER 2. VIDEODISCS

Most people first became aware of the optical media through the promotion of videodisc as an entertainment medium: the psychedelic mirrored platters or mysterious caddy-encased discs that promised the ability to watch Casablanca without the late night rerun advertisements or the pit-of-the-stomach fears of somehow tangling a videocassette tape.

Although entertainment applications are no longer the primary focus of the development work that some say will change people's lives--and libraries--they offer a clear starting point for an understanding of videodisc technology and applications.

Entertainment applications first brought videodisc technology to the attention of the general public. In these applications, the videodisc competes directly with videotape, most commonly packaged as videocassettes. From the point of view of program producers, videodisc has a number of advantages over videotape.

Videodisc has lower replication costs than videotape. The transfer of programs from master videotape to raw tape stock is a linear, sequential process. As such, it is expensive, requiring that the retail price of prerecorded tapes be set at $39 to $69 to realize a profit for the producer. This places prerecorded tapes outside the price range that most consumers are prepared to pay for home entertainment. In contrast, videodiscs can be replicated quickly and inexpensively using a stamping process similar to that used to produce phonograph records. Actual costs can be as low as $1.50 per disc and retail prices are $14.95 to $34.95.

Videodisc has other economic appeals for program producers. It is simple and economically viable to pirate

programs produced on videotape by transferring them to inexpensive blank tape stock and selling them at prices which do not include royalty payments to the original producers. The major legitimate purchasers of prerecorded tapes are the organizations that rent videotapes. Most use of videotape is now rental. Only the pirate market is doing well in the sale of prerecorded videotapes.

When pirating became a major problem in the mid-1970s, program producers set out to find a medium on which a copy of a film could be made and sold at a price of $10 to $15. This would cut out the market for pirated copies recorded on raw tape stock which then cost $9 to $11 per reel for the blank tape alone. Videodisc appeared to be the answer because discs could be produced for as little as $1.50 in quantities of 20,000 copies or more. The equipment for duplicating discs requires an investment of hundreds-of-thousands of dollars, so the average pirate would not likely set up videodisc copying facilities. While programming from videodisc can be copied onto videotape without significant reduction in image quality, the relative economics of copying are likely to limit the financial benefits of such pirating.

From the consumer's viewpoint, discs are less expensive than videotape, and can stand more wear and tear. However, videotape is more flexible because programs can be easily recorded off the air directly onto blank tape stock. The videodisc does not offer this off-the-air recording capability.

At the same time as videodisc technology was being promoted for entertainment usage, those involved in education, training and sales were developing applications in these fields. It is in such non-entertainment areas that the most significant product development is now taking place. The non-entertainment applications vary in sophistication from simple

linear audiovisual presentations to more complex programs which utilize the capabilities of players and discs developed for the industrial rather than the consumer market, and combine these technologies with computer devices. Non-entertainment applications are discussed in chapter 3.

VIDEODISC CHARACTERISTICS

It is appropriate to consider the major characteristics of the medium at this point. Not all types of videodisc offer support for all capabilities, and different types of discs and players support certain features in different ways.

The large storage capacity of the videodisc medium has received considerable attention. Discs formatted in accordance with the North American television standard contain either 54,000 or, in the extended play format, 108,000 frames of programming per side. This allows half an hour or one hour of movie-type playback per side. Discs formatted in accordance with the higher resolution European television formats contain 47,000 frames per side in regular format.

Videodiscs are capable of carrying both video and audio information. Most videodisc systems support dual-channel audio. The two audio channels can be played simultaneously or individually. High-fidelity stereo sound can be reproduced when the two channels are played together; but if stereo is not necessary each channel can contain different information--such as two different languages.

Several companies have developed techniques for recording large quantities of digital data on videodiscs. This data may be combined with audio and/or video programming and the discs can be manufactured using regular videodisc production facilities. The techniques used for recording digital data on videodisc are described in chapter 4.

In addition to offering linear, sequential playback of video and audio programming, videodiscs offer a variety of other capabilities. In a particular disc format these may include:

- o slow motion
- o fast motion, in forward or reverse
- o freeze frame, which occurs when the action is stopped in one among many frames of a motion sequence. This still-picture facility normally relies on the disc being played at a speed such that one revolution corresponds to one frame of video material.
- o still frame: this effect may be achieved through displaying a single frame designed specifically for use in the still frame mode of play (such as text, art or still photographs), or by displaying a series of identical frames from a single non-action image--an effect which occurs in motion pictures when a camera card or a slide is shot for the length of time it needs to be displayed on the screen. The technical requirements for each type of still frame display differ. The formatting of true still frame material requires special care in preparation of the program material.
- o scan, in forward or reverse. In scan mode, a player skips over several tracks at a time, displaying only a fraction of the frames it passes. This mode is analogous to skimming through the pages of a book.

Besides normal play and scanning, many videodiscs offer a third method of gaining access to the program: the search or random access function. Most players which support this feature have input keys on the machine itself or on a remote control keypad. By entering the number of the required frame --or, in some systems, the "timing" of the frame in the playing sequence of the program--the user can retrieve it with accuracy in seconds.

The ready accessibility of any frame on a disc side allows a disc to be played in a non-linear fashion--a sequence other than that in which it was recorded.

Videodiscs are circular platters, generally 12 inches in diameter, with a central spindle hole. They are made of plastic. The most common types of videodiscs have either an exposed shiny, rainbow-hued, mirror-like surface, or the surface is enclosed in a caddy to protect it from damage.

TYPES OF VIDEODISC

There are a number of different types of videodiscs. The various disc types offer different capabilities, are produced by different manufacturing processes, and require different types of disc players. Not all types of disc are commercially available in the United States, where the reflective optical videodisc is the dominant technology.

CAPACITANCE VIDEODISCS

Capacitance videodiscs share some conceptual similarities with phonograph records, the most obvious of which is the fact that they are played on equipment that uses a mechanical stylus-like device to read the programming. Unlike traditional phonograph records in which programming is recorded as physical variations in grooves on the surface of the disc, capacitance discs record programming as varying electrical charges on an electronically conductive metal disc surface covered by a layer of insulating plastic. The information is read out as capacitance variations which are decoded to present television images. There are two types of capacitance videodiscs--grooved and grooveless.

CED (Grooved) Videodiscs

The Capacitance Electronic Device (CED) is a grooved videodisc that is played using a stylus-like device, with the

stylus riding in the grooves on the disc. As the disc turns, the stylus reads the information from the disc. Because the disc is grooved and the stylus actually touches the grooves, it is necessary to protect the disc from dust and fingerprints. When not in the player, the disc is housed in a caddy or jacket.

The CED disc is a linear medium: the disc spins and the stylus rides in the spiral groove track. As commercially developed, it is not generally possible to advance a CED player to a specific, predetermined point on the disc.* All that can be done is to use the rapid access feature of the player to advance the unit at a rapid rate of speed, or to use the slow forward feature and move the display as though scanning a series of still images very rapidly. CED discs do not readily support features such as random access and frame freeze. The units usually permit only movement back and forth at varying rates of speed. If a user can remember that a particular scene occurs in the 23rd minute of the first side, it can be accessed. As a linear medium, the CED disc is best suited for entertainment applications in which a viewer watches a program sequentially from beginning to end.

A CED disc player is simple to use. One side of the disc caddy is labeled "side one," the other "side two." The player is put into loading mode using a selector lever, the caddy is pushed into the player to load the disc and then withdrawn,

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* This description of CED disc capabilities is deliberately couched in tentative terms. The characteristics of sequential access and limited still frame display are reflective of the CED technology as marketed for entertainment applications in the United States. However, these characteristics are not necessarily inherent to the medium. Shortly before announcing its withdrawal from the CED market, RCA demonstrated a CED disc player more sophisticated than those previously promoted for the technology. This player offered a greater degree of random access and freeze frame support than most commentators had been prepared to attribute to CED disc technology.

leaving the disc in place in the player. The mode switch is flipped into the play position and the program begins. To access the other side of the disc, the caddy is inserted, withdrawn with the disc, turned over, re-inserted, and the mode selector is reset to the play position. Simple CED players, which are available for around $200 in discount outlets, are monaural and have no still frame capability. There are more complex units which provide stereo sound and some still frame capability. These sell for between $390 and $480.

When recorded at maximum information density, the two sides of a CED disc can accommodate just under two hours of motion picture footage.

In the United States, the primary vendor of both CED players and discs has been RCA. Despite an investment in the technology of nearly a quarter of a billion dollars, the company announced its withdrawal from the market in 1984. The product was very slow in taking off: first year sales of the disc player were about one-third of what had been projected. Despite the fact that only about 400 CED videodisc titles were available--and dealers were frequently out of stock of many of them--disc sales were three times greater than expected. The typical CED disc sells for about $19.95. They may be priced as low as $14 or as high as $34.95 and are often available at discounts of up to 20 percent. Most programming consists of motion picture films or repackaged television programs. Because the commercially developed CED disc does not offer the selection of display capabilities or player robustness that appealed to those seeking to use the medium in non-entertainment applications, CED producers did not have access to alternate markets for players and production facilities when the technology failed to gain the anticipated degree of in-the-home acceptance.

VHD (Grooveless) Videodiscs

A second type of capacitance disc uses a grooveless technology. The Video High Density (VHD) disc has been developed by the Victor Company of Japan (JVC), an affiliate of Matsushita. The General Electric Company and Thorn EMI Ltd. are also working with this technology. The VHD format is reportedly able to play programs appropriate for display on either NTSC (the North American standard) or PAL (the European standard) television systems from the same disc. It has not been available in the United States. The grooveless capacitance disc has some advantages over the grooved disc because stylus movement is not governed by the physical tracking of a groove. This allows greater flexibility in accessing programming on the disc as the read head can be moved laterally or radially across the spinning disc. There is less wear on the disc and the stylus, and the system supports rapid random access of individual frames or sequences. VHD technology can also support freeze frame features. VHD players use a stylus ten times the size of those in CED systems.

OPTICAL VIDEODISCS

Optical videodiscs use optical techniques for program recording and reading. They are played using non-contact optical systems--such as lasers or other light sources.

The most common form of optical videodiscs are those which use laser light for playback. The non-contact nature of the player technology means that the discs are not subject to wear in the way that mechanical, capacitance systems are. There are at least two types of discs which can be read using laser technology: those with reflective surfaces, and those made of transluscent materials which permit the light to be transmitted through them. These are generally designated "transmissive" videodiscs.

Laser optical discs have similar capabilities to those provided by the grooveless capacitance technology. Players which use lasers are more expensive to manufacture, and they sell for higher prices than the capacitance systems.

Another group of so-called optical videodiscs are produced using photographic techniques and are read using a regular incandescent light source.

Reflective Optical Videodiscs

The reflective optical videodisc--sometimes known as a LaserVision or laser videodisc--is the rainbow-hued reflective disc most often used in pictorial illustrations of videodisc technology.

Reflective discs have a silvery recording surface. Programs are most commonly recorded on these discs by making patterns of pits or holes, or bubbles or blisters on a metallic recording surface. The surface is protected by a layer of translucent plastic. The variations in the recording surface produce different indexes of reflectivity when exposed to a low powered laser read head; these variations are interpreted and decoded to reconstruct the programming stored on the disc. When the laser shines on the reflective surface, there is less reflection from the pits or bubbles than from the surface that has not been written upon.

The airtight, transparent coating that encases the surface on which programming has been recorded protects it from oxidation which could adversely affect the data. The protective coating also means that the disc can be handled without damage. However, if a disc is dropped, the edges can chip and the seal of the coating may break.

Currently, reflective disc player design is such that a two-sided disc can only be accessed one side at a time--the

disc must be removed from the player and turned over if the program on the other surface is required.

The reflective optical technology is now the dominant videodisc technology in the United States. As such, this type of disc is the focus of the videodisc production and application chapters of this report. The reflective optical disc supports the full range of videodisc features, from rapid random access to individual frames to still and freeze frame display. The extent to which these capabilities are exploited in a particular disc is dependent upon the format in which programming is recorded on the disc and the sophistication of the videodisc player on which the disc is mounted.

Like CED discs, commercially produced reflective optical videodiscs formatted to accord with the North American television standards offer a choice of program capacity: 54,000 or 108,000 frames per side. When the extended-play format is chosen, many of the potentially attractive features of the medium--freeze frame and rapid random access for instance--are sacrificed.

Transmissive Optical Videodiscs

Transmissive discs are made of translucent material which is flexible. Each side of the disc can be read without turning by adjusting the focus of the light so that it shines through the disc to access the lower surface. Transmissive discs are made by Thomson-CSF in France, and are currently distributed only in Europe. The Thomson discs are read using a laser light source.

Film-based Optical Videodiscs

Several companies are experimenting with "optical" videodiscs which utilize photographic techniques for recording and replication.

ARDEV, an Atlantic Richfield company which became the Videodisk Division of the McDonnell Douglas Electronics Company, uses this process. A low powered laser is used to master the disc, but the player utilizes an incandescent light source--a light bulb--to read the disc. The use of a non-laser light source means that players are less complex and therefore less expensive than for the laser read optical systems. McDonnell Douglas is thought to be developing a desk-top mastering and replication system which will provide fast and inexpensive on-site mastering and replication and rapid turnaround. The process, from recording to mastering, is said to take about 15 minutes. The system, about which little information is available, apparently supports the full range of videodisc characteristics. A product announcement is expected early in 1985.

Eastman Kodak is also thought to be pursuing a similar technology. It appears probable that both developments will be targeted at the optical digital disk applications discussed in the next Section rather than at the more traditional videodisc application areas.

VIDEODISC FORMATS

Not only are there different types of videodiscs, there are different ways of organizing or formatting program material on a videodisc. These apply to all discs produced in commercial production facilities, regardless of the nature of their program content. The following discussion applies to both CED and reflective optical videodiscs.

Television Formats and Standards

Some details of videodisc formats are determined by the standards governing the television systems with which they are designed to be compatible. The reproduction of video in motion is created by a succession of still frames. The illusion of motion is created, in part, by the fact that the human

eye briefly retains any image impinging on it. Early work in motion pictures revealed that a rate of 16 pictures per second is sufficient to give a sense of continuity of motion. The first movies used 16 pictures per second as a standard, and most amateur movie cameras still do. The standard for motion pictures later became 24 frames per second. In television, the images are recreated at 25 pictures per second in most countries of the world and at 30 pictures per second in the United States, Japan, and some other countries. This difference originally arose to match the power system frequencies of 50 and 60 Hz in the respective countries.

Television standards address factors other than the number of frames to be displayed per second. For videodisc applications, the number of scanning lines per frame is also significant. The NTSC television signal--the North American television standard--calls for transmitting a 525-line image, 30 times a second. The total requirement is thus for scanning 15,750 lines per second. PAL and SECAM, the television systems used in Europe, the Soviet Union and most other parts of the world, operate on a 625-line scanning system.

Scanning starts in the upper left corner of the picture and proceeds across to the right and slightly downward. When the right-hand side is reached, the scanning spot retraces rapidly to a position below its starting position and again proceeds to the right and slightly downward, and so on, ultimately reaching the bottom of the picture.

However, rather than being created by one scanning sequence, a single television frame is actually the result of two scanning passes--an approach adopted to conserve bandwidth in the transmission system without introducing flicker into the image. When the scanning spot reaches the bottom of the picture, it then returns to the top and repeats the process, except that the lines of the second scan fall between the

lines of the first. The results of each scanning pass are known as fields. A single NTSC frame of 525 lines is produced by interlacing two fields each with 262.5 lines per field. Each field is generated one-sixtieth (1/60th) of a second behind the previous one.

Because the scanning spot takes some time to move from the lower part of the image back to the top to begin scanning the second field, not all of the lines in a field contain program data. There is a "gap" between successive fields. This gap, better known as the vertical blanking interval, occupies a time equal to 21 line scans. It is the moving black bar that rolls across the TV screen when the vertical hold is out of adjustment. In broadcast television in the United States, the Federal Communications Commission has defined the uses to which the "lines" in the vertical blanking interval may be put. Authorized usages include the transmission of signals to test, control, and monitor the operation of transmitters and networks during broadcasts to the public. One of the "lines" in the vertical blanking interval has been designated for the transmission of program-related data signals such as those which provide the visual depiction of information presented on the sound channel. These signals can be picked up by receivers equipped with special decoders.

In a single 525-line frame of video, field one consists of lines 1 to 262, with lines 1 to 21 for the vertical interval and lines 22 to 262 for program video. Field two consists of lines 263 to 525, with lines 263 to 284 as the vertical interval and lines 284 to 525 for program video. In the NTSC format, material recorded in this way is displayed with a vertical screen resolution of 340 lines, and 250 lines of horizontal resolution.

The program material on a videodisc is displayed on a standard television receiver or monitor after being retrieved

from the disc by a videodisc player. The player read head can be moved across a disc at varying speeds. If the movement of the head is properly synchronized with the rotation of the disc, a stable television image is produced. If the NTSC format is used, the beam must read 30 frames per second.

In videodisc technology, the vertical blanking area is used to synchronize display, to control the image producing beam while it is traveling from the lower right position of the display screen to the upper-left position, to store videodisc "chapter" and "page" numbers for control purposes, and for the timing needed to jump tracks for freeze frame, reverse play, fast forward, still picture and slow motion forward display.

Each frame on a videodisc has an address or frame number analogous to a page number in a book. The frame address is put on each disc frame in the form of a frame address code. The code is located in the vertical interval between video fields. Some videodisc systems allow access to entire disc segments called chapters. Chapter number codes are also placed in the vertical intervals.

The format in which this information is recorded varies according to the type of player on which the disc is to be played. In a regularly formatted 54,000 frame disc for Pioneer PR-7820 players, a 40-bit frame number code is entered on line 10 and line 273 in the vertical interval of every frame on the master disc. A 24-bit code must be entered on lines 17 and 18 or 280 and 181 of the vertical interval of the master disc if Sony, Sylvania, Magnavox, Pioneer, and DVA PR-7810 players are to be used. It is possible to produce discs which carry the codes for both types of players.

When a disc contains chapter number codes, some models of disc players can be made to proceed automatically to the beginning of a chapter.

Certain systems can also read picture stop codes or still codes to make the player stop automatically on a specific frame during play. Since picture stop codes are intended to be read while the player is operating in the normal play mode, the signal is encoded on only one disc frame. The picture stop function allows the videodisc designer to integrate motion and still sequences without requiring user intervention to freeze a frame.

The information on a videodisc is laid down in the form of a spiral on the disc surface. A 360-degree segment of the spiral is called a track.

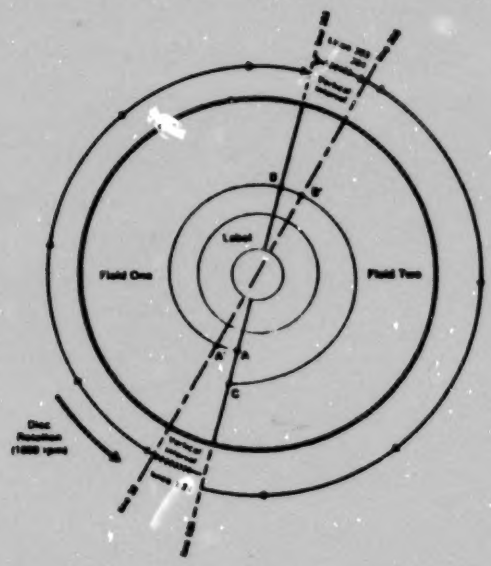
There are two different physical approaches to laying down information on the tracks of a videodisc. The terminology used to identify the two approaches refers to the type of player rotation required to display the programming: constant angular velocity (CAV) or constant linear velocity (CLV).

Commercial discs prepared under the NTSC television format using the CAV format have a capacity of 54,000 frames per side and support the full range of features offered by the particular disc technology being used. The CLV or extended play format allows a disc to carry twice as much programming as a CAV formatted disc, but the technique inhibits frame addressability and thus limits the use of freeze frame or slow motion play--when these are available as characteristics of the disc technology. Both CED and reflective optical discs are available in standard and extended play formats.

Constant Angular Velocity (CAV)

In the CAV standard play format, the centers of the vertical blanking areas for all tracks are 180 degrees apart and each track contains the two video fields that comprise one complete video frame. The disc is played at a constant rate

of 1800 rpm to achieve 30 frames per second play for the NTSC standard.



CAV
Videodisc
Format
Source: 3M

54,000 frames are mastered on each side of a CAV disc, allowing 30 minutes per side of uninterrupted play. As shown in the accompanying diagram, one CAV frame is recorded on a spiral track beginning at Point A and ending at Point C. Field one occupies that portion of the track from A to B, and field two occupies the B to C segment. The wedge shaped portions of the track are the vertical blanking intervals--A to A' for field one, and B to B' for field two.

The player begins reading the disc frame at Point A. When it reaches Point A' it has read lines 1-21 of the vertical interval and is ready to begin reading the video program in field one, which begins on line 22 and runs through line 262. In normal play, it then reads field two of the frame, starting at Point B. It first reads the vertical interval (lines 263 to 284) and then completes the frame by reading the video program on lines 285-525. When it reaches Point C it proceeds outward on the spiral track to the next frame. This is the typical program sequence for linear play.

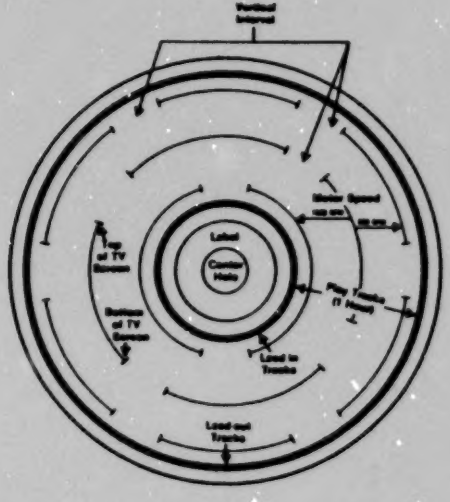
But each time the read head finishes reading the information in a video field, it can be commanded either to go on to

the next field or else to jump inward or outward to fields on adjacent tracks.

Video disc players create still pictures from any of the 54,000 frames by repeating the same tracks on the disc rather than going on to the next. Each track on the CAV disc contains one video picture, so repetition of a track results in the continuous presentation of a still frame or a freeze frame.

Constant Linear Velocity (CLV)

The Constant Linear Velocity (CLV) extended play format increases the capacity of a disc, allowing 108,000 frames of video to be recorded on each side. This supports one hour of movie programming per side, but many of the capabilities of the CAV format are forfeited.



CLV Videodisc Format
Source: 3M

On a CLV formatted disc, the lengths of the frames are constant rather than being varied so that one frame occupies one disc track—the approach used in CAV formatted discs. More than one frame can be accommodated on the longer disc tracks. The disc is played at varying speeds from 600 to 1800 rpm depending on the physical position of the track being accessed. In this format the vertical blanking areas which contain player control information are positioned in various

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places on different tracks. They cannot be as readily accessed as in the CAV format and thus cannot be used to support special modes of operation such as freeze framing and slow motion. Psuedo freeze or still frame capabilities can be provided by laying down a single image on a number of frames --four for CED systems, eight for grooveless capacitance systems.

The CLV disc can be read in linear play only. It plays in forward and scans in either forward or reverse. It can be played with dual-channel audio or stereo, and chapters can be encoded as with CAV format videodiscs. Players can search to the beginnings of chapters in any sequence on a CLV disc. To search a location on a CLV disc, elapsed time is used rather than frame numbers as on a CAV disc.

New Products

Videodisc technology and markets are extremely volatile. The latest product format is the eight-inch videodisc, introduced by Pioneer for the video music market. The company has also demonstrated a new player concept--a videodisc jukebox--to support the video music discs.

REPRODUCING TEXT ON VIDEODISC

The dominant videodisc technology is capable of providing still frame display of images. An application of particular significance to libraries is the recording and display of frames of text--pages of books and journal articles, for instance. Unfortunately, neither the television format nor the standard television screen is particularly well suited to the display of text.

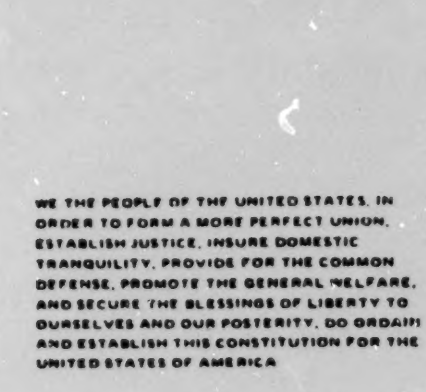
Television receivers provide approximately 250,000 pixels of resolution in a single screen display. Typically, a page of a book or journal needs to be displayed over 500,000 to one million pixels for acceptable resolution. High resolution

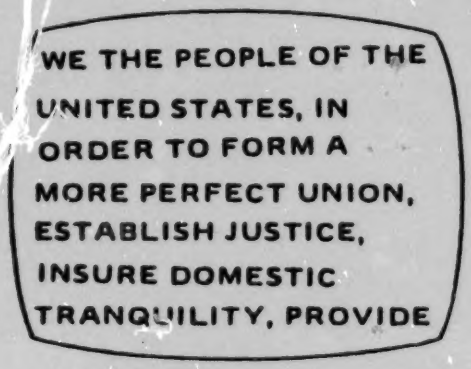
television receivers are available but they are expensive. Also, the videodisc format is designed to handle video images at resolutions akin to those supported by regular receiver technology. The acceptable display of printed information on a standard television screen is limited to 1200 or so characters per screen--20 lines of approximately 60 characters per line. (Current videotex standards provide for the display of only 960 characters per screen.) Thus, in most circumstances, the simple capture of page images on videotape and the storage of those images on NTSC-formatted videodisc will not produce an acceptable display.

Most of the applications which use videodisc for the storage of text utilize the digital and image scanning techniques described in chapter 4 and the Appendix. However, the IIT Research Institute of Chicago is pursuing a variant of the direct video approach to the storage and display of printed material on videodisc.

The IIT Research Institute has developed a procedure which allows page images to be recorded on videodisc and displayed on standard television monitors/receivers. In the IITRI Videodisc Production System (IVPS) a special high-resolution television camera is used to digitize a page image at a resolution of 2000 by 2000 pixels per page. The scanned image is examined by a computer and "de-composed" into a layout more suited for display on a television screen. The software locates columns, breaks between words, spaces between lines, etc. and determines the pieces or screens into which the page is to be decomposed. The text is rearranged so as to provide a series of screens of intelligible, readable, sequential text. The computer directs a camera to take a standard resolution "picture" of each piece and reconverts the image into a standard television signal which is captured for mastering on videodisc.

When displayed on a screen, the decomposed image is a facsimile of the original page in terms of type font and print style. It varies from the original only with regard to layout and spacing. Currently, IVPS is used to produce black and white images--details of color in an original page have not been captured using this system. Whereas early research suggested that a standard 8-1/2 x 11 inch page could be satisfactorily decomposed into an average of 5.3 frames per page, more recent work indicates that an average of 12 frames per page is required. At 12 frames per page, a CAV formatted videodisc with a capacity of 54,000 frames can accommodate 4,500 pages. The IVPS system has been used successfully to process certain types of tables and schematics as well as regular text.


WE THE PEOPLE OF THE UNITED STATES, IN ORDER TO FORM A MORE PERFECT UNION, ESTABLISH JUSTICE, INSURE DOMESTIC TRANQUILITY, PROVIDE FOR THE COMMON DEFENSE, PROMOTE THE GENERAL WELFARE, AND SECURE THE BLESSINGS OF LIBERTY TO OURSELVES AND OUR POSTERITY, DO ORDAIN AND ESTABLISH THIS CONSTITUTION FOR THE UNITED STATES OF AMERICA



Column of text

Text reformatted for screen display

Source: Peter B. Shipma. "Videodisc for Storage of Text," Videodisc/Videotex, Summer 1981, Vol. 1 No. 3, p. 170.

IITRI claims that its decomposition process is less expensive and more reliable than methodologies which store digitized images of printed pages on videodisc. It does not require the use of interfacing software to reassemble the page images, nor a special high resolution monitor to display the

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material. As of late 1984, IVPS was not being used in any production system, although the Institute was expecting to begin a test application for an encyclopedia publisher.

VIDEODISC PLAYERS

Videodisc players may be differentiated according to type as consumer or industrial (or institutional) players. Videodisc players are also often described in terms of the "level" of interactive operation they support. This concept is explored in the next chapter. The consumer and industrial players differ in the amount of control, intelligence, signal quality and robustness offered. Consumer models generally sell for around $500, while single unit costs for industrial models are around $1,500. Consumer model players are presently being marketed by Magnavox, Sylvania, and Pioneer. Industrial players are being marketed by Hitachi, SONY, DVA, Pioneer and (in Europe) Thomson-CSF.

RCA and Hitachi marketed consumer videodisc players for CED discs. Both have recently closed their CED player production lines. These employ a physical stylus and grooved videodiscs; they preclude random access and still or "freeze" frame capabilities. However, before its decision to cease supporting CED discs, RCA had demonstrated a CED player with freeze frame and addressability characteristics. Freeze frame was provided by recording the same video image on four consecutive frames. The players were not made available for commercial distribution.

To install a videodisc player on a television receiver, a cable is plugged into the output jack in the back of the player and the other end is fastened to the antenna input on the back of the television set. The channel selector is set to channel 3 or channel 4, whichever is the vacant channel or weaker station in the area.

The tracking of sales of videodisc players is one way of estimating the extent and location of the videodisc technology in the marketplace. A report published as an insert in the August 1984 issue of Videodisc Monitor (Vol. II, No. 8) examined a number of sources which track current and projected sales of videodisc players in the U.S. It estimates the population of videodisc players in the U.S. as:

Consumer market:

CED	500,000
Laser	130,000
Total	630,000

Industrial market (laser)

Arcade games	30,000
Educational	6,000
General	40,000
Total	76,000

The report also presents some information on the location of industrial videodisc players. Among the U.S. companies identified as having made large purchases were: American Motors (1,200), AT&T/AIS (350), Digital Equipment (4,000), Epcot Center (272), Ford--U.S. and Canada (4,200), General Motors (10,500), IBM--worldwide (4,400), Miles Pharmaceuticals (250), and the U.S. Army (3,100).

CHAPTER 3. INTERACTIVE VIDEODISCS

As the focus of videodisc applications has shifted beyond the reproduction of movies and television programs to education and training, point of sale and public information, and video arcade game support, the concept of interactivity has assumed greater importance. The ability to program a relatively simple and inexpensive videodisc system to sequence its presentation in response to specific user inputs now represents a relatively low level of interactivity. The most sophisticated systems combine specially formatted discs, industrial videodisc players, computers and devices such as touch sensitive screens, computer produced graphic overlays, and speech recognition input to provide multi-media systems for a wide variety of uses. Although CED disc systems are capable of supporting limited interactivity, most interactive applications utilize the reflective optical disc technology.

LEVELS OF INTERACTIVITY

Videodisc systems may be categorized according to the type of videodisc used; they may also be classified according to the range of functions they support. The Nebraska Videodisc Design Production Group has developed a classification based on player/system sophistication. The general concept of this classification has been widely accepted throughout the industry, although there is still some debate on specifics of certain elements of definition and on the number of categories that should be accommodated.

The concept of levels of player sophistication has been extended to describe the degree of interactivity between a user and a videodisc-based system that a particular mix of hardware, software and disc formatting will support. The different levels provide increasing sophistication in the user's ability to change the sequence of presentation of

the programming recorded on the disc to suit his or her own needs and interests.

Basic Level or Level Zero

Basic or Level Zero systems are those which present videodisc program information in a linear sequence. Disc players in this level do not provide still or freeze frame display and cannot access specific individual frames. The available CED players and systems using extended play (CLV) videodiscs are Basic Level systems.

Level One

At Level One, interaction is limited to simple play modes that the user can command through the control panel on the player, or a keypad. The user can go directly to any chapter or frame and can command step motion, freeze framing, forward and reverse play, scanning, and fast play or slow motion. The player can also be made to stop automatically when it comes to picture stop codes or chapter stop codes on the disc. Most consumer players for reflective optical videodiscs are Level One, including the Pioneer VP-1000 and the Magnavox 8000.

Level Two

Level Two interaction is made possible through the use of industrial or educational videodisc players containing programmable microprocessors and small memory buffers. Computer programs can be entered into the player's memory either manually (through the keypad) or by digital codes carried on the disc itself. Programming through the remote control pad can be time-consuming, and the disc player must be reprogrammed each time it is used to play a different disc. When the computer program is encoded on the videodisc, the digital program codes are carried in the second audio channel and (if that channel is on) the program is dumped into the player's microprocessor each time the disc is played. Because the microprocessor in a Level Two player generally has limited memory capacity (about 1K or 1000 bytes), complex programs may have

to be dumped in more than one step during the course of a disc program.

Some Level Two systems do not read chapter stop codes or picture stop codes, but the players' memories can be programmed so that the disc will play through a motion sequence and then stop automatically on a predetermined frame. Single frame sequences can also be programmed so that each frame remains on the screen for a specified length of time before the player steps forward or back to the next frame.

At this level of interactivity, automatic branching and simple answer analysis (based upon single key input) is possible. This allows testing with feedback on correct/incorrect answers, as well as the tailoring of sequences to menu choices or questions responses. However, since Level Two systems can accommodate only limited computer programs, the degree of branching is also limited. Many of the videodiscs produced for commercial training purposes are Level Two.

Level Two players include the Sony LDP-1000 and Discovision Associates (DVA) PR-7820. These players sell for $2,000 or more. The Thomson-CSF CED disc player--not available in North America--also fits into this category. Level Two players are faster than Level One systems, more rugged, and provide better control capabilities for the user.

Level Three

Level Three interaction offers greater program potential and capability. Level Three systems have one or more videodisc players interfaced with an external computer. The programs which govern interactivity may be stored on the external device (also described as "outboard media") or digitally encoded on the disc. Because computers have greater memory capacity than programmable videodisc players, complex programs can be supported, with the computer logging the user's

responses for testing, market research, etc. A keyboard allows the user to perform mathematical problems, respond to open-ended questions and address the computer in complete sentences. Light pens, paddles, joysticks, touch screens, voice recognition, and other devices can be used for input. Computer generated graphics and sound can be integrated with the videodisc program material. Because of the range of capabilities, computer-controlled videodisc systems are often called "intelligent" videodiscs. The player, the computer, and the program must all be compatible and properly interfaced.

Players used in Level Three systems are generally the most expensive, and cost over $3,500.

It is sometimes difficult to conceive how less than 30 minutes of linear information on a videodisc can unfold into hours of interactive viewing. A recent medical education disc, Calcium Channel Blockers, is a good example of how it is done. The system uses a Pioneer videodisc player and an Apple IIe personal computer with a disk drive. The viewer interacts by touching the monitor screen with a finger. The videodisc program is divided into nine linear sections, each with a number of short segments that last between one and five minutes apiece.

These sections take up about 25 minutes on the disc. The disc also contains four interactive sections which include nearly 1,000 still-frames of graphics. For example, there are four patient case histories that the physician must diagnose and treat. In each case, the patient's signs and symptoms are presented in still graphic displays. Each display takes only 1/30th of a second on the disc, but it may take the physician up to 30 seconds to read and interpret the information on the display. Thus 1,000 displays take up less than three minutes

program time on the videodisc, but may require an hour for a viewer to read and analyze.

Level Four

Some commentators classify advanced Level Three systems as Level Four. However, this classification has not been generally adopted because there is no common agreement on a suitable boundary between Level Three systems and the proposed Level Four.

THE INTERACTIVE VIDEODISC MARKET

Since 1979 when General Motors began using videodisc as a training and information dissemination medium, industry's use of the medium has expanded rapidly. General Motors alone has produced over 400 different videodisc programs and other companies in the auto industry have followed suit. The computer industry has also embraced the videodisc as an aid for improved marketing and education. IBM, Burroughs, Control Data, Digital Equipment, Hewlett-Packard, Apple and others use the technology. Pharmaceutical companies have been particularly active in producing continuing education programs for the medical profession.

Current estimates of the use of interactive videodisc size the 1984 market at $66 million, with 54 percent of the applications relating to training, and 23 percent each in advertising/sales/promotion/public relations and coin-operated applications such as video arcade games. It is expected that by 1993, the market will be $7 billion. A study by Rothchild Consultants projects that, in 1989, the point-of-purchase and information kiosk market will surpass the consumer market to become the largest segment of videodisc use. The report also predicts that the total number of discs being pressed for the U.S. market will grow from the current 3 million per year to 24 million per year in 1990, with roughly 15 million for consumers and 9 million for industrial use.

EXAMPLES OF INTERACTIVE VIDEODISC PROGRAMS

By mid-1984 numerous interactive videodisc programs had been produced. As will be seen in later sections, these discs--and Level One discs in appropriate formats--can often be more fully exploited using external devices to develop custom interactive programs. The following sampling of videodisc programs which support varying degrees of interactivity illustrates the range of current applications.

The National Air and Space Museum of the Smithsonian Institution is publishing videodiscs of its aviation photograph collection. The original photographs are rephotographed onto 35 mm film and transferred to videotape. The videotape is sent to 3M for disc mastering and replication.

Each double-sided disc contains 100,000 photographs (50,000 per side). Printed indices accompany each disc. The discs can be played on any standard laser disc player. Discs are priced at $30.00 each and are available from the Museum.

A National Gallery of Art videodisc documents the institution's history and offers a tour of the National Gallery of Art in Washington, DC. The disc also contains a catalog of 1,645 paintings, sculptures, drawings and prints from the Gallery's collections. The disc is accompanied by a printed index with frame numbers for accessing the art works. A microcomputer data base version of the index is being developed. Copies of the National Gallery disc sell for $95.

Videodisc Publishing Incorporated which produced the National Gallery disc, is also reponsible for two award winning interactive games discs. "Murder, Anyone?" and "Many Roads to Murder," cost $29.95 and $39.95 respectively.

The University of Delaware has published a Videodisc Music Series of four two-sided videodiscs designed for use in

the classroom or for individual instruction in music. The Videodisc Music Series includes full color video recordings of ten musical masterworks recorded in concert style. For nine of the performances there are analyzed scores that scroll across the screen in synchronization with the sound track. Four of the works also include a color-coded formal analysis displayed along with the score. The Series is available from the University for $295.

A number of companies have developed Level Three programs aimed at computing professionals. JAM's Introduction to Computer Literacy is an interactive videodisc program which comprises two double-sided videodiscs, floppy disks containing computer software, and user's and administrator's guides. The package provides 12 to 15 hours of instructional material, student testing and record keeping capabilities, and an online index and glossary. The program covers microcomputer hardware and software, telecommunications and new technologies.

The same company has also produced a series of videodisc programs introducing New Electronic Technologies. This is a series of six videodiscs with floppy disk computer software and a user's manual covering integrated systems, displays, electronic imaging, magnetic storage and retrieval, optical systems and transmission systems.

Interactive Training Systems has developed a series of specialized interactive training videodiscs with accompanying floppy disks; the program is known as the Vision series. Currently available titles include courses on UNIX, IMS/VS Data Communications Programming, and PL/I Programming.

The National Park Service has developed a disc-based information system which demonstrates the robustness of the videodisc medium. The disc--which has limited interactivity to allow Park Service staff to select the appropriate program segments--was designed for continuous information display at

specific sites. The staff select the appropriate program segment according to factors such as whether the information center is open or closed, and the number of people being processed through the center. The disc contains visitor information for a number of national parks. At each site, the player is programmed to display only the information relating to that park. During the day when the park information centers are staffed, the players are programmed to display general information. At night, different frames are displayed to direct late arrivals to campsites and indicate when park rangers will be available.

The National Parks videodisc system has been in use for more than two years. It replaced a videocassette system, and is judged to be far superior in performance. In contrast to the videocassette system, the discs are not subject to wear and the players have proved very reliable. Although sometimes located in areas of extreme climatic conditions, player failure has been minimal and can usually be corrected by routine maintenance. The Park Service had planned player backup for its initial installations at one player for every five stations. Performance has been so good that this is now being amended to one player for every 10 stations.

The only problems encountered with the application have been those relating to "screen burn-in" which occurs when a monitor displays the same frame of video for extended periods of time. A number of strategies have been adopted to overcome this difficulty. Viewing stations at sites not experiencing heavy visitor traffic are set up to be activated only when pressure sensors indicate that someone is in the vicinity of the player. Another strategy is to ensure that the different introductory screens for programming sequences set up for display at different times are designed so that the captions on each introductory frame fall on different parts of the screen.

The CPR training system developed by the American Heart Association is a much more sophisticated program which involves an industrial videodisc player, two video monitors, and a specially instrumented "Resusci-Annie" mannequin—all under microcomputer control. One monitor is used to present motion or still frames from the videodisc while the other presents computer generated graphics and text. The system provides the detailed coaching and feedback necessary to teach a person how to administer CPR. By means of sensors on the mannequin, the computer can track psychomoter parameters such as hand placement, pressure applied, and rhythm.

"The Puzzle of the Tacoma Narrows Bridge Collapse" videodisc developed at the University of Nebraska illustrates how interactivity can be used to individualize instruction according to different educational levels. This disc allows students to study and experiment with the basic principles of physics underlying the collapse of the Tacoma Narrows bridge. The material on the disc is presented at three levels of student ability: the green level provides qualitative explanations and requires a similar level of performance from the student; the blue level presents numerical calculations and expects the same from the student; and the red level involves algebraic reasoning and requires the student to observe the functional relationships between variables. The disc contains nine experiments at these three levels. It is distributed commercially by John Wiley & Sons.

A third example of interactivity is the use of videodisc to train soldiers in satellite communications ground station repair at the U.S. Army Signal Center, Ft. Gordon. The satellite communications equipment required for the course costs some $12 million and each repair involves $200 to $2,000 worth of parts. The videodisc system simulates the equipment and allows students hands-on repairs without any actual equipment. The disc displays shots of communications panels and test

equipment. The student uses a light pen to identify the location of switches, select switch positions, plug in jacks and take measurements. In addition to reducing the need for actual equipment, the system makes it possible to measure student performance in terms of accuracy and speed as well as providing the student with feedback during learning.

TOOLS FOR INTERACTIVITY

Most readers will be familiar with the components that may be included in systems which offer Level Three interactivity. For the most part the basic elements are a videodisc, a videodisc player, a display device and a microcomputer. The components for Level Three systems are often preconfigured by companies which develop the application or they may be assembled by a user from off-the-shelf components. This is not the place to detail the capabilities of microcomputers and associated devices such as touch-sensitive or light-pen-activated screens, joysticks, computer graphics, or voice input and output capabilities. However, there are four areas which deserve special attention because of their importance in fully exploiting the videodisc medium in hybrid systems. These are: the interfaces to link a computer and a videodisc player; authoring systems which allow non-programmers to design and write the computer programs to control and sequence interaction with a videodisc; the methodologies whereby audio data can be provided during still-frame video display; and the workstations that are configured for various applications.

Interfaces

There is a considerable degree of variety in the interfaces designed to link Level One and Level Two videodisc players with external computers. The resulting Level Three systems combine the interactive and immediate feedback capabilities of the computer with the audio and video programming recorded on the videodisc. Some interfaces work with only one model of disc player or computer, others can accommodate sev-

eral types of players and computers. Interfaces may support uni- or bi-directional communication between the computer and the disc player.

The linking of a videodisc player and a computer provides a program designer with the ability to develop interactive branching and sequencing instructions to utilize the material on a disc in the way most appropriate to a particular application. Different sequences can be developed for different types of users and the computer programming can be readily changed as it is not resident on the videodisc but rather in the memory device of the external computer. Provided that the disc format supports the required display capabilities, an interactive program can be developed to re-sequence material that has been recorded on a disc in a linear, sequential fashion. Segments of video from the disc can be combined and displayed in ways completely different from those which the original disc producer had in mind.

Such linkages can also support the provision of additional program input, combining text and graphics from the computer with the audio and video material from the disc. This is particularly useful when dealing with display elements that are time sensitive--the pricing information in a department store catalog, for instance. It is not however a simple process.

These capabilities provide the opportunity to develop custom applications using commercially published discs. Many of the interfaces currently available make such exploitation of disc resources relatively simple by offering both an interfacing device and authoring software which enable a user to write interactive sequencing instructions without requiring any knowledge of computer programming languages.

The physical form of interfacing devices also varies. Some are controller cards which are inserted in a slot in the computer; some use diskette software; and others have the software stored on a chip soldered on the interface card.

Most interfaces are designed to be used with disc players which utilize the reflective optical videodisc technology. The most popular machines have been the Pioneer consumer model VP-1000 and the company's industrial player, the PR 7820. Interfaces are available to support many types of computers--mainframe, mini, or micro. To date, most attention has been focused on microcomputer interfaces, with the Apple II+ being the most popular machine for such linkages. It is now being challenged by the IBM PC. There has been little interest in connecting CED players to a computer.

Some interfaces are designed to switch display back and forth between the computer's video display unit and the videodisc image displayed on a television screen or monitor, others allow a single screen to be used to display video from either source, while still others feed text or graphics from the computer directly onto the monitor displaying the image retrieved from the videodisc. Such "graphics-over" capabilities vary in sophistication and the quality of the resulting image.

Interfaces are available to support video input from both videodisc players and videotape players.

Numerous companies produce interfacing products. The following random selection of products has been chosen to illustrate the variety of interfaces available in 1984.

Allen Communications offers several computer-video interface products. The Allen Videodisc-Microcomputer Interface (VMI) links the Apple II computer with Pioneer, Sony or Magna-

vox players. Multiple VMI boards can be inserted into a single computer to provide control of multiple disc players. Associated software for simple, interactive video course authoring is available as an option. The Allen MVP (Most Valuable Peripheral) connects Apple, Commodore, or Atari micros with Pioneer, Magnavox and Sylvania videodisc players. A single screen may be used alternately to display computer graphics or videodisc displays. The interface software allows a user to set up interactive situations using available videodisc programs and includes a disc logger which allows the user to log frame numbers on the videodisc for use in programming. Allen has also developed a Universal Video Controller (UVC) which links "virtually" any computer--micro, mini or mainframe--with multiple videodisc and videotape players.

The IEV Corporation also offers a range of computer-videodisc interfaces. The IEV-40 is a controller board which allows the overlay of computer graphics on video images and provides for the computer control of videodisc or videotape players. The interface is designed for use with the IBM PC and costs $550. The IEV Model 60 is a 32-bit microprocessor interface which can also function as a micro to run programs or courseware. It has advanced graphics capabilities and provides computer-generated graphics and text which can be overlaid on the video image from a videodisc or videotape player. The interface costs $1,845.

Video Associates Labs makes plug-in circuit boards for the IBM PC. Its PC-Microkey System offers a videodisc controller capability which also supports the overlay of computer-generated text and graphics on incoming video. The product is offered at two levels which vary in the quality of image supported and the choice of disc or tape video input. The prices for the interfaces are $900 and $1,805 respectively.

Online Computer Systems Inc. markets a videodisc controller card for the IBM PC. The VDC-100 supports Sony, Pioneer, Hitachi and Philips players. Multiple cards can be accommodated to support multiple disc players. The card comes with a set of cables for one player/monitor configuration of the user's choice. Other cables are available as options. The VDC-100 (including cables) costs $350. The company provides other interfacing products including computer overlay capabilities.

Digital Research offers VidLink, an interface with control software for linking a Pioneer LD-700 to a Commodore 64, for only $49. This is the first in a series of such products. Interfaces for the Apple II and IBM PC are under development.

Videodisc Authoring Systems

Another aspect of linking a videodisc to an external computer is that of authoring--designing the computer programs for interactive use of a videodisc. Authoring systems allow people unfamiliar with computer programming to build and implement training, educational and business packages using a computer. The user of an authoring system is able to develop the appropriate computer program by responding to menus and prompts rather than by programming. Authoring systems are not necessarily developed specifically for videodisc applications and may be more general in scope to support any form of sequencing and branching which rely on computer control. Several of the available systems were initially developed to help non-programmers develop interactive computer-based instruction courseware.

Authoring procedures and systems vary according to the sophistication of the interactive systems being created and the method by which the programming is to be recorded. The procedures are more complex and critical when the computer program to control an application is to be encoded on the

videodisc along with the audio and video material. In this situation, the program logic and the machine-readable coding must be developed in conjunction with the other material to be recorded on the disc, and the program must be fully debugged and exhaustively tested--both for internal logic and for location pointers to disc materials--before the videodisc is mastered. Authoring systems to support such applications are complex and might more correctly be described as premastering editing systems.

Such factors are less critical when the controlling program is to be loaded into a computer from a floppy disk or other storage medium. In these circumstances the computer program can be readily changed or amended as it is not encoded on the disc itself.

Many of the products available to interface a videodisc player with a computer also contain basic authoring software to allow an instructor to develop interactive sequences using existing videodisc materials.

In addition to including some authoring capabilities in the interface devices described in the previous section, Allen Communications also offers a separate general purpose authoring software package. QUEST is aimed primarily at educators or content specialists who wish to produce computer-based training materials. It includes color graphics and animation capabilities, as well as special features for the incorporation of audio and video sequences from videotape or videodisc. A variety of question and answer formats are supported along with sophisticated branching capabilities and student performance monitoring and reporting sequences. Configured for the IBM PC, the QUEST software is priced at $595. QUEST for Apple II micros is $495.

The WICAT Interactive System for Education (WISE) can compose text, design graphics displays, outline progress through courseware, and define criteria for evaluation--all without computer coding. It uses a menu-driven, natural language approach. Commands written in ordinary language produce instant results on the screen. A graphics editor allows the author to create a wide variety of instructional displays.

McGraw-Hill's Interactive Authoring System (M-H/IAS) is a software package designed for the IBM PC or XT micro. It includes a Management System to record trainee results, and programs developed on the system may include interactive video segments and computer simulations.

V:Link 1000 from Visage, Inc. is a printed circuit board and floppy disk software product that links an IBM PC with any laser videodisc player, provides authoring capabilities for the production of animation and graphics, and supports the display of the graphics alone or overlaid on images from the videodisc. It is priced at $1,150.

Online Computer Systems, Inc. offers an authoring or courseware development system known as PILOTplus, an enhanced version of the Programmed Instruction Learning or Teaching (PILOT) system. The system enables course developers to combine color graphics, graphics and text over video, touch sensitive panels, light pens, joysticks and sound technologies. The software is available in versions compatible with most microcomputer operating systems. The version for the IBM PC costs $500. A fully configured authoring system comprising the authoring software, an IBM PC with two drives, a Sony monitor, a Pioneer videodisc player, an IBM printer, the VDC-100 controller card and an IBM color graphics card costs $6,000. In addition to authoring systems, the company also configures networks of student and instructor workstations.

Sound Over Still

The videodisc's ability to display still-frame images is valuable for the storage and retrieval of large visual data bases. However, the development of some applications has been hampered by the difficulties associated with providing audio programming to accompany the still frame video display. On CAV discs, still frame capabilities are provided by playing a single video frame continuously. Only 1/30th of a second of audio can be encoded in the audio channel of a video frame. When the video frame is displayed in still frame mode, the audio is also reproduced continuously; the same 1/30th second is repeated 30 times per second, resulting in meaningless sound.

This difficulty can be overcome by mastering a disc so that the video and audio use the appropriate channels on different frames. The video can be displayed in still frame mode while the player accesses and plays the frames that have been encoded with audio data. These frames serve no purpose other than to support the audio passage. This uses the storage capacity of the disc at a very high rate. A second of audio uses 30 frames of the videodisc. Thus if a 10-second narrative is provided for a single still frame, 300 frames are used for the audio plus one for the visual. In this mode, the capacity of one side of a CAV formatted videodisc with 54,000 frames would be only 180 still frames with 10 seconds of audio for each still image.

In order to utilize the potential high capacity for still image storage on videodisc in applications which require accompanying audio, various "still-frame audio" or "sound over still" systems have been created. The approaches vary in their complexity, cost and appropriateness for different applications.

The simplest systems use two independent storage media: a videodisc containing image data with an audio cassette player providing sound for still pictures. Systems such as Delex's Discmate 1.5 provide an interface between a regular stereo cassette recorder and a videodisc player, allowing the outputs from the two devices to be synchronized as required. The audio material can be readily modified by the system user. This approach has drawbacks for non-linear applications due to the sequential nature and lengthy access time of audio tape.

Another approach to the provision of audio support for still images entails the conversion of the audio information to digital form. This process is described in the Appendix.

Once the audio has been digitized, two options are available: the data may be stored on a computer peripheral such as a Winchester hard disk, or it may be further processed and mastered on a videodisc using the techniques for digital data recording described in the next chapter. Either approach supports rapid random access and retrieval of the audio data. A selection of the companies providing products that support the digitizing of audio data is included in the next chapter.

Workstations

The use of the videodisc technology for a wide range of business, information and training activities has spurred the development of numerous special purpose workstation or display station designs. While it is possible for an individual or company to purchase all the components and configure them as required, there appears to be an increasing trend toward purchasing a preconfigured station from a company which serves this market, providing the program producer with a "turnkey" approach to supporting a particular videodisc application.

This is not surprising given the variety of components in such a station: disc player, monitor or television receiver,

computer, computer memory peripheral, printer, and an input/response device which may include keyboard, lightpen, touch screen, etc.

Many interactive workstations include a touch screen to serve as the input device for users' responses. Education and training program designers feel that the touch screen puts the viewer in control of the program, even when he or she has absolutely no knowledge of computers, typewriter keyboards, or keypads. The touch screen also allows the viewer to maintain eye contact with the program at all times. There is no need for the viewer to look away--to push buttons on a keypad, for instance. Partly because of the constant eye contact with the images and partly because of the physical act of touching the visuals, viewers seem to develop a certain level of intimacy with the program.

There are three major types of touch screens based on different technologies--infrared sensor, capacitance, and membrane. An infrared sensor is used by Hewlett-Packard in its HP-150 personal computer. Rows and columns of sensors are mounted in a frame around the screen. The coordinates of a touch point are generated when a beam is broken by the finger of the user. The resolution of infrared screens is usually 25 rows by 40 columns. Because the beams are somewhat removed from the screen, this type of device is sometimes subject to inaccuracies, particularly when a finger or object touches the screen at an extreme angle.

Capacitance screens operate by detecting minor changes in the electrical current at the point touched. They are capable of much higher resolution than the other screen types but are more expensive to produce. A membrane screen is used in the Sony Universal Monitor. It works by the action of touch pressing two fine membranes together, and provides accuracy with economy. The resolution of the touch screen supported by

the membrane approach is similar to that provided by infrared sensors.

The work or display stations are usually configured by companies that have another interest in the videodisc field--be it as program designers, production houses, or hardware and software developers. Companies actively promoting their workstation or display packages include Videomagic Laboratories of Rockville, MD; NCR Interactive Training Systems Inc. of Cambridge, MA; Level Four Interactive, Inc. of San Francisco; Visage, Inc. of Natick, MA; Allen Communications of Salt Lake City, UT; Online Computer Systems, Inc. of Germantown, MD; Raytheon Service Company; TriLogic of Santa Monica, CA; and Digital Equipment Corporation.

CHAPTER 4. RECORDING DIGITAL DATA ON VIDEODISC

There are at least two methods of recording digital data on videodisc. In both approaches the digital data is included in the videodisc programming that is mastered and replicated in quantity runs using the regular commercial videodisc production facilities and procedures described in the next chapter.

The first approach--digital dumps--accommodates only limited amounts of data and is generally used to record player control instructions on interactive videodiscs designed for use in Level Two systems. A more recent development—the premastering of digital data on videotape in the NTSC format--allows vast quantities of digital data to be recorded, and replicated, on videodisc. Any type of digital data may be "published" in this way--machine-readable ASCII coded alphanumerics, bit-mapped image data and digitized audio data.

DIGITAL DUMPS

Prior to the development of techniques for encoding large quantities of digital data in the NTSC format for replication on videodisc, it was possible to record only limited amounts of digital data on videodiscs. The data input is generally computer programming designed to be downloaded from the disc into the memory of Level Two videodisc players to support interactive and branching operations. Such data is generally referred to as a "digital dump." The format in which digital dumps are recorded is determined by the brand of the videodisc player on which the disc is to be played. The data dump formats for Pioneer and Sony players are different and a disc producer may choose to follow one or the other format. It is also possible to input the data in both formats--as "tandem" dumps which allow the interactive capabilities of the disc to be exploited on either player type.

The data is stored on the second audio track of the disc. Disc manufacturers impose extra charges for mastering and replicating discs which contain such data--3M increases its normal set-up charge by $2,500 per side on non-rush orders. Keying of the digital data to be encoded in this way may be undertaken at the disc replication facility or the customer may provide the data on floppy disk or by telephone transfer.

The videodisc player control data encoded in digital dumps does not require the use of special premastering equipment, nor does its retrieval entail the use of interfacing capabilities other than those provided in Level Two players. However, the digital data storage capacity offered by this approach is limited.

RECORDING DIGITAL DATA IN THE NTSC FORMAT

The Lister Hill National Center for Biomedical Communications of the National Library of Medicine was a pioneer in developing techniques for the recording of large quantities of digital information on videodiscs and its playback via regular industrial videodisc players. The work being undertaken at Lister Hill was eclipsed when a small company in Massachusetts, LaserData, developed a proprietary method of converting digital data into the analog FM codes used on videodiscs. The LaserData technique is based on research undertaken by MIT.

A number of other companies have also developed proprietary processes similar to those used by LaserData to encode digital information on analog videodiscs. These methods, which store from 25 to 100 MB of digital data per minute of video run time, all require the performance characteristics of reflective optical videodiscs. Firms active in the field include Online Computer Systems, Inc. of Germantown, MD, Reference Technology Inc. (RTI) of Boulder, CO, and Tomax Inc. of Montreal, Quebec. The companies which have been most aggressively promoting the application are LaserData and RTI.

The digital data to be mastered on the videodisc is recorded on videotape. The proprietary processes are those involved in recording the data on videotape, and checking the transfer to detect errors. Production of the discs from the tape follows the regular videodisc production procedures described in the next chapter and uses commercial mastering and replication facilities such as those of Sony and 3M. The discs are played on regular reflective optical videodisc players. Special interfaces are required to enable a computer to access a videodisc player like any regular computer storage peripheral. On playback, a controller reconverts the analog signal to digital form, and sends the digital data to the computer.

Using this technique, CAV formatted videodiscs can accommodate up to 1.2GB of digital data. The actual amount of usable storage depends upon the error detection and correction techniques applied. Although the procedures for publishing digital data in this format have been available for some time, applications are only now being brought to the market. It is not yet possible to assess the performance of such systems.

LaserData

In the LaserData system a special calibration frame containing a known quantity of data is displayed when the disc player is powered up, so the lowest error rate can be achieved. The various gray scales used to encode the data are clearly shown in the calibration frame. Using the LaserData technique, the capacity for a 12 inch disc side is 1.16GB of raw data, with 30 percent overhead used to correct errors, giving a usable data storage capacity of 800MB of user data per side. Raw bits error rates on the LaserData discs pressed by 3M are said to be between 10^{-4} and 10^{-5}. Corrected error rates of 10^{-12} are cited. The videodisc--known as the Data-Disc when produced using the LaserData technique--may be single- or double-sided. Charges, including mastering, are

$800 each for a minimum order of 10 discs, $450 each for 25, and $17 each for more than 2,500 copies.

Currently the LaserData technique is being used only for the production of 54,000-frame capacity CAV discs. The amount of information stored could be doubled by going to CLV format, but searches would take three times as long.

LaserData presently supports only the Sony LDP-1000 and the Pioneer 8210 players; it is intending to develop support for the the faster Hitachi, Philips and Pioneer models. The company's approach is to use existing, off-the-shelf players rather than to develop a proprietary player. The only part of the retrieval hardware that is product specific is the Laser-Data Document Controller, the "black box" that interfaces the player and the computer and performs certain error correction functions. The controller is priced at $2,950. The company is expected to release a controller that will fit into the expansion slot of an IBM PC. The product is due for release early in 1985 and is expected to be priced at around $1,500.

LaserData provides two services: the encoding of digital data on videotape ready for disc mastering, and the supply of workstations to access the data on the discs. The company also serves as an intermediary between the client and the disc mastering facility.

The DataDisc Mastering Service (DMS) uses a proprietary means of encoding digital data onto a videotape which is then mastered and replicated by a commercial production service. The resulting videodiscs are called DataDiscs. The charge for encoding and replication depends on the format of the disc, and the number of sides.

The discs will support a mix of audio, digital and video data. If committed solely to digital data storage, the discs

have a capacity of 800MB--15,224 bytes per frame with standard error correction. Video capability is 54,000 frames; and the disc can accommodate 75 hours of digitized audio data--or appropriate mixes of the three information types. The average access time is 1.5 seconds. The maximum data transfer rate supported by the LaserData interface is 400KB per second and the corrected error rate is reportedly better than 10^{-12}.

LaserData offers nine distinct workstation configurations tailored to the differing needs of potential end users. Most employ a selection of optical videodisc players linked by a controller to a professional-standard microcomputer.

The minimum hardware configuration for a workstation includes the LaserData 100 Controller--the interface that links the videodisc player to the micro--and the LaserData 101 Professional, a work station with a microcomputer, one terminal and a single videodisc player. The average workstation costs approximately $18,000, but the company has configured workstations for as little as $5,000. A more sophisticated station--using a Sony player, an IBM PC and the controller--costs $13,000.

Configurations such as the LaserData 102 Researcher can support four players thus quadrupling the online capacity of the system. It can also support three additional terminals. The LaserData 301 is a complete image retrieval and analysis work station with four players. The 301 includes image processing software, high resolution display capability, and monitors with touch-sensitive screens for interactive programs.

Another feature of the LaserData DataDisc product is an optional encryption process designated DataDefender. A disc publisher can put several data bases on a single disc and provide a customer with the access "keys" only for those data bases to which the user has bought access rights.

The company sees its primary market as the publishing industry: publishers of reference works, directories, texts and periodicals for medical, legal, scientific, academic, engineering and business professionals. It is believed that this group will find the medium's ability to store full, searchable machine-readable text, illustrations and video in both still-frame and movie format most attractive.

Reference Technology Inc.

Reference Technology Inc. of Boulder, CO announced two products/services in its CLASIX product line late in 1984: the TRIDECC error correction and premastering process which converts digital data from magnetic tape to videotape, and the DataDrive videodisc player and interface which serves as a computer peripheral to read the data from the videodiscs and make it accessible to the computer system. The name "TRIDECC" derives from the company's proprietary three-dimensional error correction coding techniques. The DataDrive, which uses a proprietary videodisc player, is designed so that multiple units may be stacked together. Costs to system integrators depend on quantity and range from $3,325 to $5,000 per player. Controlling software and other components raise the price to $5,900 and $8,900.

RTI can configure multi-user systems which allow multiple users to simultaneously access data on a single DataPlate (the name given to videodiscs produced using RTI technology) on a single DataDrive. The DataDrive is a CAV player which can be attached to any micro or minicomputer which supports the SCSI interface. It is capable of transmitting data to the host computer at a rate of approximately 1.2MB per second. Optional components include a CLV capability which enables the system to read DataPlates encoded at twice the capacity of standard CAV DataPlates. When operated in this mode, the average access time is longer. A video option is available to enable the DataDrive to read DataPlates that have motion or

still frame video and audio sequences intermixed with digital data.

RTI says its procedures achieve high data storage with low error rates and fast access times for relatively low prices. Capacity for the storage of user data--after error correction--is cited as 1 GB per disc side. Record access times are fast, with a reported average seek time of 125 milliseconds for CAV formatted discs. Replication costs are quoted as being in the region of $15 per copy for a disc produced by the TRIDECC premastering process and replicated by 3M in a quantity of 1,000 copies or more. The cost for the production of a single disc--only one copy produced--ranges from $5,000 to $10,000.

The TRIDECC system offers error correction capabilities which reportedly reduce the error rate to 10^{-13}. The procedures entail the use of a three-dimensional Read Solomon code with 26 percent redundancy at 1GB per 12 inch disc side. The company claims that its procedures are capable of accepting the input of raw data with error rates as high as 2×10^{-2} and still delivering output error rates better than 10^{-13}. Large bursts of errors in incoming data can be corrected by the procedure. The 1GB per side capacity of the DataPlates is the effective capacity after error correction.

The production process for DataPlates is similar to that used by other companies recording digital data on analog videodiscs: the machine-readable data is captured on half-inch magnetic tape; using the TRIDECC system, the data is premastered onto one-inch videotape and subjected to error correction techniques; the videotape is then submitted to a regular videodisc mastering facility such as that operated by 3M for mastering and replication. The resulting DataDiscs must be played on the DataDrive players.

RTI's plans call for the development and marketing of a lower capacity single-user read only computer peripheral. This is expected to be released in 1985.

Tomax

Tomax, a Canadian company, offers services similar to those of LaserData and RTI. However, it is unusual in that it offers the equipment used in transferring digital data to NTSC tape format for sale to end users. The company also offers the digital to video service at its own facilities in Canada.

Released in August 1984, Tomax's PM-1000 premastering system is a small (19 x 23.2 x 7 inch) unit which contains a CPU, a Winchester disk drive, and various input/output and other controllers. The PM-1000 accepts analog audio and digital data from any source and converts it to the NTSC format for recording on videotape using a standard 1-inch helical videotape recorder. The unit also includes authoring software using the Pilot Plus authoring language. In single quantities, PM-1000 prices begin at $28,640.

The Tomax LCP-1000 workstation includes a microcomputer, a videodisc player, and the appropriate interfaces to support the retrieval and display of data from the videodisc. In single quantities, it is priced at $9,750.

A Ph

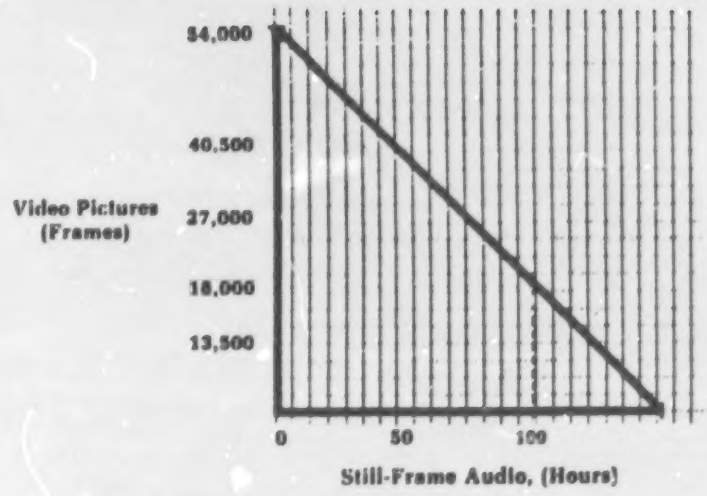
A Ph Technological Consulting of Pasadena, CA recently announced a product similar to that of Tomax to allow a producer to premaster in-house the digital data for videodisc publication. The company offers two devices, an encoder and a decoder. The A Ph technology does not offer the same storage densities as the other products discussed in this chapter. The promoted data storage capacity is 375MB per side for discs in the CAV format and 750MB per side in the CLV format. The

VDC-2 data encoder plugs into an IBM PC slot and is priced at $36,000. The VDC-1 decoder also plugs into any IBM PC and decodes the data from the disc. It costs $1,000. The system allows the mix of digital data and video on the same disc.

Other Companies and Products

LaserData and RTI have promoted their services to clients interested in using the videodisc medium to publish ASCII coded machine-readable data. Another group of companies entered the arena because of their interest in providing sound over still audio capabilities through the replication of videodiscs containing a mix of video and digitized audio data.

The EECODER system developed by EECO Inc., of Santa Ana, CA compresses digitized audio by a 300 to 1 ratio and formats the data as a standard video television image on videotape. The tape is then mastered using regular videodisc production techniques. One video frame can accommodate 10 playback seconds of audio. The amount of still frame audio can be varied to meet the requirements of each still image--from one to 40 seconds per image. The playback quality of the sound is the equivalent of AM radio. As this method utilizes the video component of the NTSC format, the regular audio channels can still be used for additional audio programming. A frame which contains compressed audio data in video form cannot also accommodate a pictorial image. If all 54,000 frames of a CAV disc were devoted to compressed audio data, the disc would contain 150 hours of audio playback. Most applications present a mix of still-frame audio and video images. Regular motion and sound sequences can also be recorded on the same disc. The mix of video and still frame audio that can be accommodated on a CAV formatted disc using the EECO system is illustrated in the following chart.



Source: EECO

The EECODER System has two microprocessor-controlled units: the AVC-300 Still-Frame Encoder, which compresses and formats the audio program material during premastering, and the VAC-300 Still-Frame Decoder, which captures and decodes the compressed audio during playback. The decoder uses standard NTSC signal processing techniques to recover the compressed audio and accepts the NTSC-compatible video signals from all popular videodisc players. Decoding is fast--four frames of audio can be decoded in 120 milliseconds. The decoder can switch between audio from the regular audio recording channels which provide stereo sound to still-frame audio. A serial interface allows external control of the convert and playback functions via any popular microcomputer.

The audio information is recorded on video frames adjacent to the desired video still-frame image. When the system plays back, it "recovers" the audio from the video, then parks on and displays the desired video image. As the viewer is watching the picture on a TV monitor, the "recovered" audio is played back. Segments of audio, once recovered, may be played more than once without changing or losing the video picture under user control.

Sony and Pioneer offer similar still picture with sound products.

Online Computer Systems, Inc. manufactures a DSA-100 Digital Sound Adaptor Card for the IBM PC. The card provides an interface for retrieving digitized audio data from a Winchester hard disk. It offers high quality sound over still capability for interactive applications requiring large amounts of sound. The unit supports a playback period of from 8 to 32 seconds and has been designed to store sound segments in memory to be recalled on demand. The card will also read digital data from a videodisc. The DSA-1000 costs $1,500.

Problems

The limited availability of commercial videodisc products encoded with digital data makes it too early to assess the success of the various techniques for encoding digital data in the NTSC video format. Some problems are expected. Paramount among these is the identification and correction of errors. Mastering and replication procedures for videodisc production do not allow dynamic error identification and correction. There are many sources of errors in the production process, including errors in mastering and replication, and errors due to flaws in the materials used in disc production. Errors occur in the production of videodiscs for entertainment purposes. These errors, while often visible, are seldom obtrusive to the eye or ear. The sensitivity of machine-readable digital information to errors is much greater, since the loss or change of a single bit could cause a computer program to malfunction, or an index to return wrong information.

The theoretical, error-free storage densities for the recording of digital data on videodisc are estimated to be between 2 and 4 GB per 54,000 frame side. The amount of usable data per side depends upon the types and magnitude of the errors encountered in the mastering and replication of the digitally encoded videodiscs and the error correction methodologies used in the premastering process. There have not yet been sufficient operation applications to enable an assessment

of the claims of the various companies actively pursuing the publication of digital data on videodisc.

The fact that the digital data is encoded in the NTSC video format means that the validity of the data cannot be checked during the disc mastering and replication process--the data cannot be reconstructed without using a computer and the appropriate controller or interface. Disc replication facilities such as those of 3M are not equipped to provide such capabilities--their standard dropout (error) measuring equipment is keyed to inspecting video images. If there was a sufficiently high volume of discs containing digital data, appropriate equipment could be installed to inspect the discs electronically, but there might be some reluctance to take this step because of fears of being involved in exposing clients' proprietary data.

The absence of standards is another concern. Different companies use different error correction and detection approaches requiring special software for data retrieval and interpretation. Products from the two companies most actively promoting the process--LaserData and RTI--cannot be used on the same player. LaserData provides flexibility in configuring its decoder as a separate component that can be attached to a number of player/computer combinations; RTI requires the use of a proprietary player or drive.

Outlook

For mixed-media applications combining image, audio and digital data, the reflective optical videodisc technology appears to be viable. The appeal of recording digital data on the videodisc in such applications will depend on the nature of each application--the extent to which program designers wish to incorporate the digital data as an unalterable, internal element of the program, rather than supplying it from a

readily updatable external source such as a floppy or Winchester disk.

The successful publishing of data bases using optical videodisc technology will depend on a variety of factors, among them technical soundness, cost, user acceptance, and adherence to standards. Early entrants will probably find it necessary to provide their customers with the hardware as part of an annual subscription fee, rather than depending on them to invest in the purchase of equipment.

CHAPTER 5. VIDEODISC PRODUCTION

Until recently all videodisc production was undertaken in large commercial facilities geared to quantity production. This remains the dominant approach, but in the past twelve months other options have become available. These include commercial facilities which specialize in the production of low volume videodiscs--generally 1 to 10 copies of a program--and the development of systems which support the production of limited quantities of videodiscs at the user's site.

COMMERCIAL MASS REPLICATION

Commercial videodisc production occurs in three distinct phases. Phase one--program design/production--may be as simple as selecting the movie or television program to be reproduced on a disc. In the development of de novo programming for distribution on disc, this step includes the definition of program objectives, the preparation of a script, the storyboarding of picture and sound sequences, and the development of audio and video material for the program. For interactive discs in which the controlling computer commands are to be included on the disc, the appropriate sequencing and branching instructions also have to be plotted, coded and tested.

Phase two is the post production/premastering stage. It involves the preparation of the video tape to be submitted to the disc production facility for mastering and replication. Premastering includes the transfer of program material from tape, film or slides to video tape. It includes color and contrast correction, cue insertion and editing. The premastering processes may be the responsibility of the disc producer, a production studio, or a premastering facility.

Phase three is the mastering and replication of the disc. This is undertaken at a commercial disc production facility.

The disc producer checks the premaster tape for adherence to published specifications. A master disc is then made from the tape, the master is replicated in the quantity ordered, the discs are checked for conformity to specifications, packaged, and delivered to the customer.

It is difficult to determine precise costs for phases one and two of disc program production; the amount of work involved varies enormously depending on the program being produced. The replication of existing motion picture or television programs can be very inexpensive, as can the development of simple interactive programs using existing still images or video footage. On the other hand, the design and development of sophisticated, highly interactive medical education programs such as those sponsored by various pharmaceutical companies can run to hundreds of thousands of dollars. The transfer of older video materials to disc can also entail high "hidden" costs because of the premastering precision required to ensure that the final program is capable of supporting the full range of videodisc features such as slow motion and freeze frame. The most predictable components of videodisc production costs are the mastering and replication charges levied by disc production facilities. These are detailed in readily available pricing schedules.

Program Design and Production

Designing and producing a videodisc is similar to writing, producing, and directing a film, except that the interactive potential of the medium demands special effort in planning and sequencing. Hidden in both film and disc development are layers of various media and hours of evaluation.

This stage of disc production is simplest when single media programs are being prepared. Little planning is required if a disc is to carry a pre-existing audio and video program transferred from videotape or slides, or in the trans-

fer of digital data. Catalogs of existing still images can also be assembled with relative ease, provided the source materials meet the requirements of the disc medium. If sound over still audio is to be supported on the disc format, greater planning is required in positioning the various frames of audio and video data. Applications which mix multiple media--still images, motion images, regular and sound over still audio, and digital data--can require extremely careful planning, even down to the story boarding or flow charting of the contents of every frame of a disc.

When program materials are produced de novo, the procedures and expenses associated with each form of media also need to be assigned to the disc project. In elaborate programs, the costs can include the hiring of script writers, actors, camera crews, production staff, instructional media experts, and programmed instruction developers.

The nature and extent of interactivity in a disc program underlies many of these factors. The more complex the branching and programming in an interactive application, the higher the cost of producing the disc. The total cost of developing the programming for an interactive videodisc can range from $15,000 to $250,000 or more.

There is little published information on this aspect of videodisc production costs, and the costs are so application-specific that what is available is not necessarily widely transferrable. In the August 1984 issue of Videodisc Monitor (Vol. II, No. 8), an article by Steve Floyd of Coca-Cola USA presents a cost breakdown for producing a 30-minute training disc--in 100 copies--using three different approaches to programming: linear, programmed instruction, and programmed simulation. The writer assumes that all material for the disc is produced de novo. The total costs are similar for all

three approaches--and for the alternative to the linear option, the production of the program on videotape: $58,000 ($56,000 for the videotape option), $54,500 and $56,500 respectively. The major cost element in each case is for video production--$30,000.

Premastering

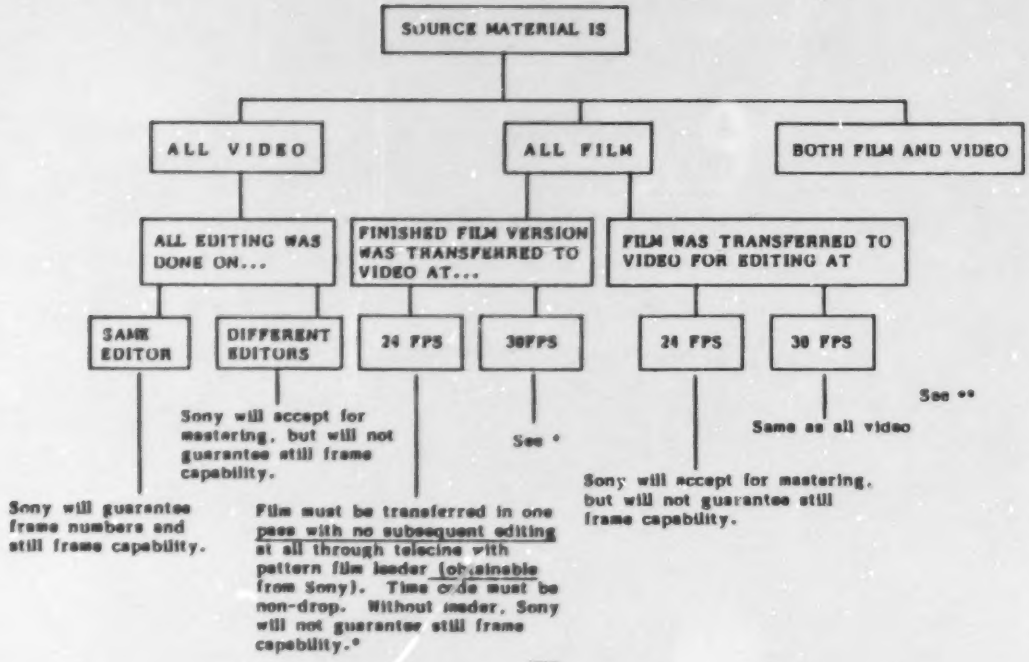
Once the videodisc program has been designed and the appropriate materials assembled, they have to be combined on a single videotape for dispatch to the videodisc mastering and replication plant.

That the premastering process for even relatively simple mixed media videodiscs is a complex endeavor is illustrated by the following excerpts from the videodisc premastering and formatting instructions issued by Sony Video Communications and 3M's Optical Recording Project, two of the major reflective optical videodisc production facilities.

> "Was the original material shot on film or video? The original material is considered first generation, a copy from that would be second generation, and so on. Provide an exact description of the source material, and the subsequent dub-downs, whether film or video. Make clear the relationship, expressed in generations, of the submitted master tape to the original material. (For older material being recycled for disk, this may involve careful investigation)." Source: Sony.

> "For interactive programming include a complete and understandable flow chart which explains in detail exactly how the program will be viewed. All segments and still frames must be identified with time code. A complete set of program control instructions for the Sony player must be included, either as hard copy from the Sony disk simulator or in other form authorized by Sony."

"Still frame utilization: The ability to access and display a single frame is one of the unique characteristics of the laser disc system. (Note that "single still frame" refers to a unique single frame on the master tape. Usually, these frames are instruction or data frames with text. It does not refer to "freeze framing" one of many frames in a normal motion sequence.) However, utilization of this still-frame capability calls for extreme care in production. Unless this care is exercised, you will not be able to access and display single frames." Then follows a page and a half of detailed instructions, the gist of which is summarized in the following chart from the Sony brochure:


SOURCE MATERIAL IS
ALL VIDEO
ALL FILM
BOTH FILM AND VIDEO
ALL EDITING WAS DONE ON...
FINISHED FILM VERSION WAS TRANSFERRED TO VIDEO AT...
FILM WAS TRANSFERRED TO VIDEO FOR EDITING AT
SAME EDITOR
DIFFERENT EDITORS
24 FPS
30FPS
24 FPS
30 FPS
Sony will accept for mastering, but will not guarantee still frame capability.
See *
See **
Same as all video
Sony will guarantee frame numbers and still frame capability.
Film must be transferred in one pass with no subsequent editing at all through telecine with pattern film leader (obtainable from Sony). Time code must be non-drop. Without leader, Sony will not guarantee still frame capability.*
Sony will accept for mastering, but will not guarantee still frame capability.

Sony requires the use of a flying spot scanner, such as a Bosch or Hank. Failure to use top level FSS telecine will prevent still frame capability due to lag between frames.

** Two approaches may be taken for still frame capability in these cases. (1) All still frames are put in one video segment, which is insert edited into the film portion of the program. You must specify the start and stop points of the still frame segment. (2) Finished film version is transferred to video (with no video editing) as above, and still frames are in film portion only. In this case there can be no still frame capability for video segments which are insert edited after the film is transferred.

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"... a video frame is made up of two interlacing fields, one following a sixtieth of a second behind the other. Field one consists of lines 1 to 262, with lines 1 to 21 for the vertical interval and lines 22 to 262 for program video. Field two consists of lines 263 to 284 for the vertical interval and lines 284 to 525 for program video". Source: 3M

"In most previous uses of video tape, it has mattered little whether field one precedes field two or vice versa--the constant, uninterrupted alternation of fields creates an appearance of smooth flow from picture to picture. But videodisc players can be instructed to interrupt motion sequences and continuously reread a single frame. When the videodisc player stops on a frame containing fields recorded from different pictures, a disturbing effect known as flicker or jitter is created on the television screen". Source: 3M

"... flicker may be caused by mismatched fields. It occurs when fields from two different frames are read together as a single disc frame. The only way to avoid mismatched fields it to pay careful attention to field dominance, or the order of video fields established on video tape during edits or transfers. A tape of field one dominance is one in which a new picture begins on field one with field two dominance the new picture begins on field two. The field dominance of the premaster tape determines on which field the videodisc frames will begin". Source: 3M

"Complications arise when a premaster tape changes field dominance at one or more points within the program. This may occur unwittingly. It happens most often when tape is edited on equipment incapable of frame-accurate editing or on equipment that has selectable field-accurate editing. When a tape has one segment with field one dominance and another field two dominance, one of these

segments (depending on how the mastering equipment is set) will have freeze frame flicker throughout". Source: 3M

"Specify the make and model number of all video recording and editing equipment used in the production of the submitted tape. For each editor used, specify whether this is a first field or second field editor. Note: Sony will not guarantee still frame utilization if different editing systems are used in the same program". Source: Sony

"Other important design considerations relate to the length and numbering of disc chapters. It is recommended that no chapter be less than 30 video frames long. Chapters may be numbered from 0 to 79, inclusive. A disc side may begin with any chapter number the designer indicates; all subsequent chapters on the side will then be numbered consecutively, in increasing order from program beginning to end. If chapters are to be used on a disc side, all segments of that side must contain chapter number codes. This means that even introductory material on a chapterized disc side must also bear a chapter number. Chapter zero is often used for this purpose". Source: 3M

Obviously, many of the problems portended by such warnings can be avoided by careful research and planning or by placing the preparation of material in the hand of a production bureau or personnel experienced in the use of the videodisc medium. At this relatively early stage in the history of videodisc production, such expertise is not always readily available in-house, and not all potential disc program producers have the resources to retain individuals or services with the required experience.

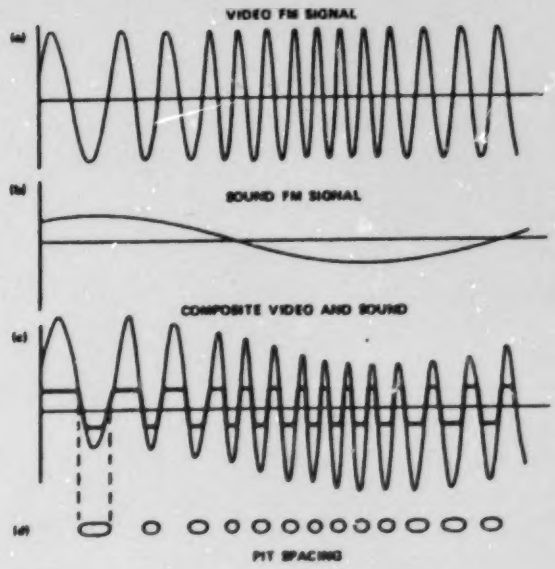
Mastering and Replication

Commercial mastering and replication techniques do not vary with the application that a program is designed to

support. However, different processes are used to manufacture CED and reflective optical videodiscs. This account focuses on reflective optical videodisc production because of the dominant position of this type of disc in the market.

All videodiscs produced in quantity are manufactured by making a master disc of the programming which was recorded on videotape in the premastering phase. Copies of the disc are then replicated from the master. There is a variety of manufacturing processes both for the production of the master disc and for the replication of copies from the master, and each disc manufacturer is somewhat secretive about its processes.

In the creation of a master disc, the video and sound signal from the videotape are combined and converted into a single FM signal. The tops and bottoms of the FM signal are clipped to make a pulse code modulated signal. As illustrated below, the signal is an "on-off" digital-like signal, but one in which properties other than the presence or absence of the signal have meaning--the length and spacing of the signal elements also have information content.



Source: Fred E. Marsh, Jr. "Videodisc Technology." Journal of the American Society for Information Science, July 1982, p. 239.

The variations in the signal pattern are used to drive the device chosen to record the information on the master videodisc. In most cases, that device is a medium powered laser light source.

In the Philips disc mastering process--that most commonly used--the master disc is a glass disc coated with a photoresist layer of material that reacts to light. The master is rotated under a laser beam, the intensity of which is modulated by the signal from the videotape. The laser sensitizes spots in the photoresist layer. The photoresist is then developed so that the sensitized spots become pits.

This master disc may be replicated in a number of ways. One of the most common is injection molding. In this technique a layer of metal is electroplated onto the "developed" photoresist surface of the master disc so that the pits become bumps in the metal layer. The metal layer is strengthened and used as an injection mold.

Discs are produced from plastic in an injection molding machine at high temperature and high pressure, the bumps on the mould creating pits in the surface of the disc. The plastic disc formed by this process is then plated with metal to make a reflective surface. Two disc surfaces are bonded together to form a two-sided videodisc.

There are problems with the injection molding process. The high temperature and pressure environment creates wear on the mold and introduces stresses into the plastic. There must be clean separation and no warping when removing the disc from the mold and it is important to protect the surface from dust and other contaminants between the time that the disc is removed and the metal plating applied. The process has built-in delays as the disc cannot be removed from the mold until the plastic has cooled.

Another method for producing discs from a master is the photopolymerization (2P) process. It is used by 3M to replicate discs from masters made using the Philips technology. The 2P process entails the creation of a mold almost identical to that used in the injection process, except that it does not have to be as strong. A liquid form of the same plastic used in the injection process--but one which is sensitive to light --is placed in the mold which is then exposed to ultraviolet light. The plastic solidifies and pits are formed in its surface by the mold. The disc is removed from the mold and the pitted surface is metal plated to form a reflective surface. This process is not subject to problems of high pressure and high temperature, but the plastic still requires time to harden. Compared with the injection process, the 2P mold costs less and requires less time for set up. Sony and Pioneer also use the 2P process for disc replication and the same process is used in the manufacture of compact audio discs.

Turnaround times between the delivery of a videotape premaster to a disc production facility and receipt of the multiple copies of the final disc vary. Turnaround is influenced by a number of factors: producers of complex programs sometimes choose to contract for a preliminary "proof" disc to enable the accuracy of the program to be checked before mass replication is undertaken; scheduling at a production facility can cause problems; etc. In order to overcome such disappointments, a number of production facilities now offer "rush" service, promising same day, one day, or three day turnaround --for additional charges. "Normal" production times vary, but may require two to three full working weeks.

Replication Costs

The disc mastering and replication charges levied by the major disc production facilities vary according to the format of the disc being produced. Different pricing scales apply

depending on whether the disc is one- or two-sided, regular (CAV) or extended play (CLV) format, and extra charges are entailed if the disc includes internal computer programming--digital dumps--to drive Level Two players.

The charges levied by 3M in 1984 were:

Discs with no digital dumps:	1 side	2 sides
Set-Up		
Regular play	$1,800	$3,600
Extended play	$2,500	$5,000
Copies		
1-99	$18	$23
100-499	$14	$20
500-999	$12	$17
1000-1499	$10	$15

For quantities in excess of 1499 copies there are no set up charges and discs are available at the following prices:

1500-1999	$10	$15
2000-2499	$8.50	$12.50
2500-4999	$6.75	$10.50
5000+	Prices on request	

Discs which contain digital dumps are available only in regular play format and are more expensive:

Set-Up $2,500 per side, regardless of quantity

Copies		
1-999	$18	$23
1000-1999	$15	$21
2000-2999	$12	$17
3000-4999	$6.75	$10.50
5000+	Prices on request	

3M offers fast turnaround on limited numbers of disc copies. Same day, one day and three day options are available for set up charges ranging from $2,700 to $5,000.

Pioneer's charging structure is simpler, but the company stressed that it requires two weeks' warning in advance of the production process and that turnaround takes three working weeks:

	Mastering # Sides	Replication First 1000	All Over 1000
Regular play	1: $2,100	$10 each	$7 [illegible]
	2: $4,200	$15 each	$12 [illegible]ch
Extended or	1: $2,400	$14 each	$10 each
interactive	2: $4,800	$19 each	$15 each

A proof disc--a single replica of the master--can be obtained for $500 per side and a five-day turnaround; 24 hour or 36 hour service on proof discs is available for double the price.

Pioneer offers "expediated special service" on disc production. The minimum turnaround for a one-sided disc is 24 hours and there is an additional set up charge of $1,800; for a two-sided disc, the extra charge is $3,600 and the minimum turnaround time is 48 hours. Three, five, and ten day service is also offered for premium prices.

Manufacture of Capacitance Videodiscs

Capicitance systems also use a mastering and replication clean-room facility.

In the production of grooved capacitance (CED) disc masters, the recording is undertaken at a speed 25 times slower than the real time playback speed. This is because the band width of video signals is so wide that they cannot be recorded directly in the grooved medium and instead are "time stretched" before recording. The discs are produced in a process similar to the manufacture of a master phonograph recording, and the duplicates are made by a stamping process.

The production procedure for VHD discs is similar to that for grooveless discs. The recording medium is a glass disc in which the information is recorded in pits. A metal master is produced from the glass disc. This is used to manufacture "stamper" discs which are then used to produce the final discs by a stamping process.

Manufacture of Transmissive Optical Videodiscs

The manufacturing process is an embossing process which should be significantly less expensive than the molding used in most reflective optical disc production techniques. The system also differs in its treatment of audio material. This is recorded in a digitized form in the vertical blanking interval of each field.

"Shared" Videodisc Production

A recent innovation of interest to organizations wishing to take advantage of the videodisc medium but requiring the production of less than a full disc for their presentations, is the concept of sharing a disc with other organizations having similar requirements. This is the approach taken in the National Park Service disc described in chapter 3, but in that case the Park Service served as the "agent" in arranging the shared production undertaking. Several companies active in the provision of videodisc production services are now promoting disc sharing. Trilogic of Santa Monica, CA promotes its ShareDisc concept, offering linear or interactive videodisc "time" for $300 per minute. Online Computer Systems Inc. of Germantown, MD is promoting a similar type of approach to museums with the apparent objective of developing an image bank resource that can be used in a variety of applications.

LOW VOLUME COMMERCIAL REPLICATION

The low-volume fast turnaround videodisc options provided by commercial mass replication facilities utilize the same production techniques as their high-volume runs. However, a number of products and services have been developed by other vendors specifically targeted at the low volume market. These are described in the following pages.

LaserVideo, Inc.

LaserVideo, Inc.--the research and development arm of the Quixote Corporation--has developed a method of disc mastering and replication that permits local, and rapid, production of reflective optical discs. Turnaround times of less than 30 minutes from completion of recording to playback are quoted. The process utilizes a glass master disc with a metal surface. Holes are made in the metal surface in the same pattern as the pits in a Philips master. Copies are produced by bringing the master disc in contact with a plastic blank that has been pre-coated with a reflective metal surface. The master is exposed to light which penetrates through the holes in the metal. The copy is processed to create identical holes in its metal surface. These holes have the same function as the bumps in the discs made by the injection and 2P processes.

Quixote claims that the LaserVideo process has a number of advantages over other reflective optical disc production methods: the master is not exposed to high temperature or pressure and it is in contact with the copy for only a short time. The fact that the metal plating is applied to the discs before mastering means that discs with faulty coating can be weeded before the mastering process. The discs can be played on any commercial reflective optical videodisc player. The company expected a product to be on the market sometime during 1982. In fact, it was not until September 1984 that Laser-Video announced that it was accepting orders for the Laser-Master product. The company is not yet offering quantity service, limiting its operations to the production of one to three copies of a disc, all of them de novo masters.

LaserVideo's discs are available on same-day and one-day turnaround at less than one-half the price of other expedited videodisc manufacturing services. The company sees appropriate applications as trade show exhibits, client presentations, program development, and applications where videodisc content must be updated frequently and each disc is unique.

It is also expected to appeal to program producers who want trial discs to monitor the performance of a videodisc program before going to large scale replication.

The LaserMaster disc is not a replicated disc. Each disc is made direct from the client's videotape. Extra copies of the disc are produced using the videotape to master another, identical, disc. The disc is made of high quality optical glass bonded to plastic and will play on standard laser-based videodisc players. The company plans to expand its present service to encompass production of replicated discs in the future. The process used in the production of LaserMaster discs can also be used to produce compact audio discs, CD ROMs and optical digital discs.

Pricing is based on quantity and speed. Same-day, one-day, two-day and six-day turnaround is available. The price per side for the first disc for these options is: $2,000, $1,750, $1,500, and $1,200. Additional copies of the same side are priced at $1,500, $1,250, $1,125 and $900 respectively.

The company is also offering an 8-inch videodisc format which contains 24,000 frames, or just under 15 minutes of program material. The discs are compatible with laser-based videodisc players. Prices range from $600 for 6 day turnaround to $1,000 for same day turnaround--half the price of the 12-inch laser master discs.

In-house Systems

Most discussions of videodiscs describe the medium as a read only technology in which programming is produced by preparing a master from which copies are replicated. While this is true of the vast majority of videodiscs, it is now possible to purchase equipment to support the production of small quantities of videodiscs in-house.

This development increases the possibility for confusion between videodisc and optical digital disk. It is important to remember that the distinguishing feature of videodisc is that it utilizes a video (television) format regardless of the type of data being recorded.

Several companies market equipment to support in-house videodisc production.

Panasonic offers blank 8 inch optical discs for video recording in two formats: spiral (TQ-FH224) and concentric (TQ-FD22). The spiral discs have a storage capacity of 24,000 frames, 60 percent greater than the capacity of the concentric discs which, at normal recording resolution, store 15,000 frames. The spiral discs will accommodate either 24,000 still images or approximately 13 minutes of motion video with two channels of audio. Data is recorded on the discs in the NTSC video format. Programming recorded on a disc is accessible as soon as it has been written. No processing is required. The discs are priced at $260 each.

The company markets four different units for recording video data on the blank discs. All can also function as players. The TQ-2023F Motion Video with Audio/Still Optical Disc Recorder can be used with either spiral or concentric discs and offers two audio channels for recording and playback. It supports playback at any speed up to 30 frames per second. The system will accommodate either motion picture or still frame recording. It is priced at $34,900. The company is apparently phasing out its three other video recorders in favor of this unit.

The TQ-2022FC Color Single Frame Recorder with Motion Playback utilizes concentric discs and costs $24,900. It will support playback at 30 frames per second. The TQ-2021FBC High Resolution B/W Still Video Recorder accommodates only black

and white images. It was promoted as being especially suited for document storage and was priced at $18,900. The TQ-2020FC Color Still Video Recorder utilizes concentric discs to store up to 15,000 color images at normal resolution. It was priced at $18,900 and supports playback at 20 frames per second.

One separate player unit is offered--the TQ-2024F Motion Video with Audio/Still Video Optical Disc Player. Priced at $3,975, the unit supports playback from both spiral and concentric discs and can display motion video with sound, or still video frames. Each frame on a disc is individually numbered and can be accessed in "about half a second" by punching in the required frame number on a keypad. Both the standalone player and the recording units have RS232C interfaces which enable playback to be placed under external computer control. Interactive applications can be supported in this way. Random access, still frame and variable speed playback are standard features.

A semiconductor laser is used for both recording and playback. The signal is recorded on the disc face as a chain of pits with variations in reflectivity. One frame of video is recorded on one track.

To configure an operational system using the Panasonic video recording equipment a number of other system components need to be added to the blank discs and the recording unit. A system for applications such as interactive videodisc development or image management would also require a camera for image input, a monitor for display, a computer--if external computer control was required--and various interfacing cables. One system integrator estimates the price of a configuration using the TQ-2023F recorder and an $18,000 camera at $84,000.

Among the companies developing applications using the Panasonic hardware is Multi Image International of New York,

NY. It sees the technology as being applicable to archival storage and retrieval, inventory control and product identification, film and videodisc premastering, x-ray and medical imaging storage, interactive learning program development, library and museum collection management, real estate and travel guides, time lapse recording and computer graphics applications.

Hitachi is also marketing a videodisc recorder similar to the Panasonic products. The VIR-10000 Optical Video Disc Recorder utilizes 8-inch discs capable of storing 24,000 still images or approximately 13 minutes of motion video per side. The unit is available in at least two different configurations, one optimized for the recording of black and white images in high resolution, the other designed for color. Like the Panasonic units, the VIR-10000 records in real time, providing immediate playback without requiring any processing of the disc.

The Optical Disc Corporation of Cerritos, CA introduced a more sophisticated--and more expensive--videodisc recording system in the middle of 1984. The 610 Videodisc Recording System allows in-house production of low volume fast turnaround videodiscs which may be played on any standard reflective optical videodisc player. The system utilizes full-size grooveless discs which may be recorded in either the CAV or CLV format. In CAV format the discs can accommodate 54,000 frames or thirty minutes of motion; in CLV format, 60 minutes of motion programming can be provided.

The Recordable Laser Videodiscs (RLV) are single-sided and data is recorded in the form of pits. Each copy of a disc is produced individually; the technology does not support mass replication of discs. Without quantity discounts, the blank RLVs cost $100 each.

The Recording System consists of the 611 Studio Recording Console and a 612 Encoder/Generator. The Encoder/Generator formats the program materials for replication. It will handle regular motion, still and audio input and will also process digital data into the NSTC format. Output from the unit can be fed to the recording console for the in-house production of single discs or it may be transferred to videotape which can be forwarded to a commercial videodisc mastering and replication facility. For a self-contained in-house disc production system both components are essential; together they are priced at $200,000. A high resolution monitor package is also available.

CHAPTER 6. COMPACT AUDIO DISCS AND CD ROM

The compact audio discs being promoted by the music industry share many aspects of the technology used in videodiscs. The dominant compact disc technology, that promoted by Philips and Sony, uses optical laser recording techniques and optical playback systems similar to those developed for reflective optical videodiscs. The compact discs are replicated using similar mastering and stamping techniques. A 4-3/4 inch one-sided compact audio disc provides one hour of high quality stereo playback. As with videodiscs, a capacitance audio disc system has also been developed but it does not appear to be enjoying any significant commercial success.

While conceptually similar, there is one major difference between compact audio discs and videodiscs: the nature of the signal which is recorded. Videodiscs store information in the standard television format. All data--image, audio, or digital--has to be converted to this format during the premastering process. By contrast, the compact audio disc is geared to the encoding of audio data directly in digital form. Rather than representing the analog signals of television video, the pattern of recorded impressions on the compact audio disc represents digital data. (The process of converting analog sound waves into digital form is described in the Appendix.)

As of late 1984, the compact audio disc appeared to be doing well in the consumer market. Music programming was becoming more widely available and compact disc players were available at reasonable prices. There were, however, no dedicated compact audio disc mastering facilities in the United States.

CD ROM

Because it is designed to store data in digital form, compact audio disc has obvious appeal as a digital data mass

publishing medium. Any form of digital data can be represented--character coded, image or audio--but most attention is being focused on the use of the medium for character encoded applications such as data bases and computer software distribution. In such applications, the disc is generally referred to as CD ROM (compact disc read only memory) or OROM (optical read only memory).

Developments in this use of compact disc appear to be progressing much more rapidly than did the use of videodisc as a digital publishing medium. One reason is that two of the companies that developed the technology--N.V. Philips and Sony--have agreed to a common standard for the compact disc format. Under that standard, 4-3/4 inch CD ROM discs have the capacity to store 550MB of digital data.

As the CD ROM application of compact audio discs is a relatively recent development, and one not yet widely supported in the commercial market, other advantages of the medium have not been as widely publicized as those for digital publication on videodisc. CD ROM can be expected to share or, if given sufficient product support, to surpass the digital data storage characteristics attributed to videodisc.

By the end of 1984 at least five manufacturers had announced plans to distribute CD ROM players in North America. Hitachi, North American Philips, Sony, Panasonic, and Denon America, Inc. have demonstrated prototype players and are expected to have production models available early in 1985.

CD ROM players or readers are similar to those developed for audio discs. They are designed to be more rugged and error detection and correction capabilities have been increased.

Current CD ROM specifications posit storage capabilities of 500 to 600MB on a single-sided 4-3/4 inch disc, track to track seek times of one millisecond, total access time averages of half a second, and worst case access times of between one and two seconds.

At least one company--Sony--has indicated that it is working on developing a "writable" compact audio disc system. It would support not only the in-house recording of music and other audio data, but also digital data. Matsushita is working on an erasable compact disc system.

CHAPTER 7. VIDEODISCS AND CD ROM AS DIGITAL PUBLISHING MEDIA

Discussions of optical media frequently address the technology's promise as a digital storage device. Until the development of the techniques for encoding digital data in the video format developed by companies such as LaserData (described in chapter 4) it seemed that the only optical media that offered practical promise for digital data storage were the various optical digital disk systems. In such systems the validity of the data being recorded (written) is dynamically checked by reading the data as soon as it is written. Discrepancies between the data read from the disk and that fed to the input or write mechanism are detected immediately. The storage address of the defective data is deleted from memory, and the data is rewritten onto an unused part of the recording medium. The drawback from the point of view of "publication" --ready replication and distribution of data in this form--is that optical digital disk systems as presently developed are not designed for mass replication. Data stored on such a system can be copied, but only by sequential reading and rewriting.

Although there are as yet no established commercial applications of the technique, the medium initially promoted for the mass replication or publication of digital data is the videodisc. Conceptually, the videodisc is an ideal medium for the mass replication of digital data recorded on the disc in digital form. However, this is not the scenario in which applications of the medium for digital publishing has developed. [This approach is taken in the more recent option--the use of compact audio discs for the publication of digital data.] When videodisc is used to record digital data, the data is encoded in analog form as a standard NTSC video signal and the disc is copied using the same mastering and replication processes employed for commercial videodisc production. This technique of recording digital data as video information

--which some observers believe has still not been demonstrated to be effective--requires no special production facilities other than the premastering equipment for the transfer and verification of the digital data to a videotape as an interim storage medium.

Delays in the application of this option now make it possible that the use of videodisc as a digital data distribution medium may have limited appeal. This is because of the development and market penetration of the compact audio disc. If industry analysts are correct, the adoption of CD ROM--the replication of digital data on compact audio discs--may well leap-frog similar applications of videodisc. If this happens, the videodisc may be the preferred publication medium for digital data only when that data forms part of a more extensive presentation that also includes significant quantities of moving and still frame image data.

ADVANTAGES OF VIDEODISC AND CD ROM

The reflective optical videodisc and CD ROM have a number of features which make them attractive media for digital data publication. Given the current read-only capabilities they will not supplant the use of traditional read-write digital data storage media such as magnetic tape. Any threats to these media will come from the optical digital disk systems described in later chapters.

A major advantage of using videodisc or compact audio disc for the publication of digital data is that there is so much standard equipment available for it: for mastering and replication, and for playing or "reading." Production costs are relatively low and, for videodisc, a sirgle disc can present a mixture of different forms of information: digitized data of any type, and analog audio and video information.

Most machine-readable data is currently delivered to remote users by shipping magnetic tape via commercial couriers or by transmitting data over voice-grade telephone lines. The former is an inflexible medium which requires reloading onto magnetic disk for effective access and manipulation. The latter is expensive--usually $5 to $25 per hour of transmission time.

The information storage capacity of the standard videodisc and compact audio disc offer significant advantages over other media. However, comparisons are often misleading as not all proponents clearly identify the types of data and the videodisc formats used in comparisons. Such factors have considerable influence on storage capacities. The so-called "standard" videodisc format--the CAV format--when encoded with NTSC video signals, offers 54,000 video frames per side for information storage. However, digital data can also be recorded on videodiscs in the extended CLV format. Information recorded in this format cannot be accessed as quickly as that on CAV formatted discs, but the CLV discs can carry 108,000 frames of information per side--double the capacity of a CAV formatted disc.

Neither do commentators adequately specify the form of data used in capacity comparisons. This problem is particularly evident in comparisons which cite disc storage capacity in terms of "pages," but it can also be found in references to audio storage capabilities. As detailed in the Appendix, there are dramatic differences in the amounts of digital data required to represent the information content of an ASCII-coded page compared with a digitized image representation of that page. Similar problems arise with loosely defined references to the capacity of various media to store digitized audio data. The playback time of the amount of audio represented by "x" bytes of digitized data is dependent upon the coding scheme used to digitize the audio which in turn is

determined by the type of audio being recorded--speech or master music performances, for instance--and the quality of sound required in playback.

With these caveats, the claims for the digital data storage capabilities of one side of a CAV formatted optical videodisc are impressive:

- o the equivalent of over 2,000 5-1/4 inch double-sided, double-density floppy disks,
- o a coded ASCII text capacity 30 times that of high density magnetic tape,

as is the more precise statement of error corrected storage capacities of between 8MB and 1GB per side. Information on the storage capacity of CD ROM is more precise, as the medium is designed specifically for digital storage.

A one-sided disc, which adheres to the standards developed by N.V. Philips and Sony, has a storage capacity of 550MB. As the CD ROM application of compact audio discs is a relatively recent development, and one not yet supported in the commercial market, other advantages of the medium have not been as widely publicized as those for digital publication on videodisc. CD ROM can be expected to share or, if given sufficient product support, to surpass the digital data storage characteristics attributed to videodisc in the following paragraphs.

The economics of videodisc storage of digital data are favorable, but it is important to remember that the current technology supports only the "storage"--or, perhaps more reflective of the types of applications being developed, "publication"--of digital data. The videodisc is not currently promoted as a read-write medium; as commercially developed it supports only read access.* Thus, while the economics of

* However, several companies have begun to offer units which allow a user to produce single quantity videodiscs on-site. These products are described in chapter 5.

using videodisc as a storage medium may be extremely favorable, it cannot perform as a direct substitute for the magnetic or optical disk media with which it is often compared.

In discussions of the cost advantages of videodisc as a digital data storage device, the cost per megabyte of storage is frequently cited. In such comparisons, videodisc costs of one half of one cent per megabyte are said to be 40 times less expensive than magnetic tape, 400 times cheaper than floppy disk, and over 800 times less expensive than removable magnetic disks.

The videodisc has other advantages, including volume and weight characteristics which are valuable in applications where large data banks have to be maintained or distributed over a wide geographic area. The high density of the disc's information storage capacity makes it extremely effective for data storage and distribution. One hundred videodiscs occupy one square foot in volume, weigh less than 40 pounds and, if replicated in quantity, may cost less than $50 each to manufacture. Although providing no indication of the storage method--coded digital data or digitized image data--one commentator offered a striking data storage comparison: 100 videodiscs can store more information than a library of 100,000 volumes, each with 1,000 pages, occupying a total of 10,000 cubic feet, and costing several hundred thousand dollars to purchase.

The weight advantages of the disc are significant in considering applications in which physical distribution of data is important. In one illustration, an observer states that 400 pounds of paper is required to store 1GB of information and that the same information stored on floppy disk would weigh 40 pounds. In comparison, 1GB of data can be accommodated on a videodisc weighing only one-third of a pound. The cost of transferring a megabyte of such information from Los Angeles to New York by Priority Mail was examined. Needless

to say, the lighter weight videodisc made its shipment stunningly less expensive than the cost of transferring the data online over the telephone system.

Given that production costs are related to duplication time, the replication techniques used with videodisc are advantageous especially when compared with magnetic tape or optical digital disks, both of which require sequential copying. The videodisc medium also appears to have distinct advantages in terms of projected archival life which is estimated at around ten years--considerably better than most existing computer storage media, but similar to that projected for optical digital disks.

However, neither videodisc nor CD ROM can support the access speeds provided by traditional magnetic disk storage devices. Access times are also very slow when compared with Winchester drives which offer access in 30 to 50 msec. CD ROM appears to support access speeds between one-tenth of a second to one second with worst case access of four seconds. Advocates of the technologies suggest that these speeds can be significantly improved by attention to the layout of the data on the discs and by the development of specialized software for access and retrieval.

VIDEODISC VERSUS CD ROM

Reference has already been made to a major difference between digital data recording on videodisc and compact audio disc or CD ROM: in the former the data is recorded as a video signal; in the latter the methodology is more directly digital. This difference may be expected to have implications for the comparative performance of the media as digital publication vehicles. Videodisc mastering and replication facilities cannot check the quality of the recording of digital data. Compact disc production facilities--there are none yet in commercial operation in the U.S.--are set up to handle digital

data and the validity of that data can be monitored during the mastering operation. This difference may mean that digital data recorded on compact audio discs contains fewer errors than that published on videodisc.

The videodisc is unique in its ability to combine motion and still images, audio, and digital data on a single disc with rapid random access capabilities. For interactive applications requiring a mix of video and any other forms of data, the videodisc is the only suitable medium.* CD ROM can support digital and audio data but not video information (unless it has first been digitized). Videotape can provide the same mix of information as the videodisc, but it lacks the speed and economy of replication, and the random access capabilities of the disc.

In all other characteristics, the videodisc does not appear to outperform CD ROM. The determining factors in any battle between the contending media are likely to include sponsorship by major companies (IBM is rumored to be pursuing the CD ROM as a read-only digital data store), the availability and cost of mastering facilities, and the availability of low cost players. These were some of the factors which resulted in the acceptance of the reflective optical videodisc over other forms of videodisc in the United States. However,

* This statement may no longer be correct. Matsushita has announced the development of a method for storing video images along with music on a standard compact audio disc. The announcement indicates that any of the following forms of information can be stored on a disc: 4,500 one-second alphanumeric frames which could be used for displaying lyrics or musical instrument interactions, 1,800 two-color pictures, or 350 16-color frames. The application being suggested is the recording of music singles and video with up to seven minutes playing time. It has not been possible to ascertain details of the techniques used in the product, but the caveats about color in the image frames suggest that the video may be obtained from digitized images rather than from television imagery.

in that situation, the greater capabilities of the reflective disc medium were also significant.

As yet, the limited availability of commercial products in either format precludes judgment as to the relative capabilities of the two media in production systems. It is possible that the sophisticated error detection and correction procedures used by companies such as LaserData and RTI in preparing digital data for videodisc publication and incorporated into the interfaces that decode the information for end-user applications will result in very high quality performance. Also, it is as yet unclear how much data validation will be incorporated into CD ROM mastering and replication procedures.

Videodisc, with its larger size and consequent higher storage capacity, may continue to have appeal for the publication of very large files of data. On the other hand, CD ROM has a potential advantage in that there is a standard for digital data storage on the medium. No such standard has been developed for the recording of digital data on videodisc, and the two major U.S. proponents of this technology produce incompatible discs.

Nor is it possible to forecast the relative economics of the recording media and the associated player/drive systems. Trends in consumer applications of compact audio discs suggest that the CD ROM may enjoy advantages. Current estimates are that some 300,000 compact audio disc players have been sold and that there are some 700 sound recordings available in this format. Players cost $495 to $995 and discs retail at around $18. The prices of both players and discs are falling. A few discount houses already offer both at 30 percent off the list price.

In addition to a mastering charge of $1,800, audio discs cost $3 to $5 per disc copy to produce. The cost of CD ROM

production is expected to be slightly higher than audio discs --$5 to $8 per disc--because of the need for better quality control with machine-readable data.

The future of digital data publishing on videodiscs and compact audio discs is heavily dependent on the direction of market developments in both technologies. If current rumors are accurate, CD ROM applications should appear on the market in early 1985, probably with the support of major computer hardware and software companies.

CHAPTER 8. OPTICAL DIGITAL DISKS

The videodisc and compact disc media described in the preceding chapters have mostly been developed as read-only media, employing prerecorded discs produced in quantity. The absence of a recording capability at the user's site is generally not seen as a disadvantage in entertainment, training or publishing applications. Among program providers it is welcomed.

The situation is different for computer mass storage and business or office automation applications of optical technologies. In these areas a system which allows the user to write or record data as well as to read or retrieve it is essential. Such capabilities have been developed in the optical digital disk which is the basis for a number of computer storage peripheral and office automation product announcements.

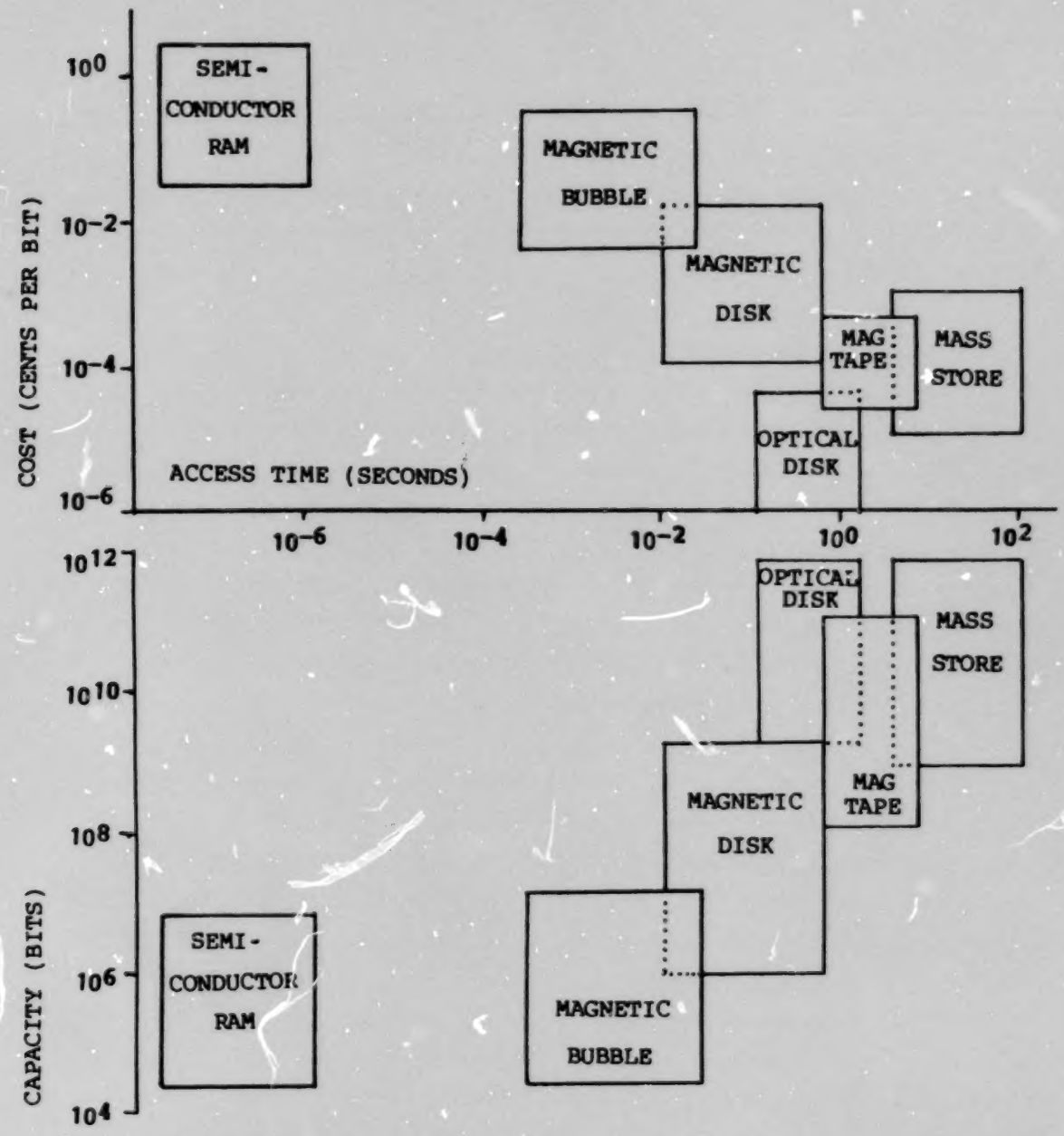
Despite much lauding of the promise of the optical technologies for such applications, products are only now beginning to appear on the market. Current optical technology does not support erasability--the ability to erase data written on the medium and re-write new data in its place. The lack of erasability is a major difference between the optical disk media and traditional magnetic storage media such as tape and disks. The traditional media are erasable and can be re-used once the data stored on them is no longer required. A number of companies are researching methods of providing erasability in optical media. Their efforts are detailed in chapter 10.

Why, then, the excitement over a medium that apparently has less to offer than existing technologies? The basic driving forces--as with the read-only technologies discussed in the previous chapters--are performance characteristics and economics.

"Performance characteristics" include a plethora of capabilities, referring not only to the data storage capacity of optical-based media, but also to related quality considerations such as error rates, the speed with which data can be recorded on the medium, and the time required for the location and retrieval of data so stored. Among the attractions of the media are environmental considerations such as the relatively small physical space required to house an optical storage system, the tolerant temperature and humidity requirements, and the lack of susceptibility of the medium to magnetic, electrical and other types of interference. As is the case in relation to the predominantly read-only optical media of videodisc and compact audio disc, discussion of the comparative advantages of optical digital media is clouded by the variety of different systems and technologies being developed. This is exacerbated by differences in the performance characteristics of laboratory and custom developed systems and those relatively few products which are currently available in the commercial market.

Performance would be meaningless were the optical digital storage technologies so expensive as to offer no cost advantages over existing storage systems. Because of the comparative infancy of commercial optical-based storage systems, many of the claimed cost advantages are based on assumptions of a degree of market penetration that has not yet been demonstrated. However, in specific applications, the claims, even when modified for the slower than projected penetration of the technology, are impressive.

It is common for cost-performance comparisons of optical digital disk and other media to be represented in charts, such as on the following page.



Cost and Performance of Various Mass Storage Media

After: Processing and Data Distribution Within the Research Libraries Information Network. Part V: Technology Assessment. Stanford, CA: The Research Libraries Group, Inc., November 1983. p. 22.

PERFORMANCE CHARACTERISTICS

Comparisons of the relative performance of optical storage technologies and traditional magnetic storage media routinely address the characteristics outlined in the following paragraphs.

Information Storage Capacity

High end optical storage systems offer significantly greater information storage capacities than magnetic tape or magnetic disk systems. Computer mass storage peripherals capable of storing 4GB of user data on one side of a 14 inch optical disk are now available. The actual capacity of the disk is greater, but not all of the capacity is available for the recording of user data: between 20 and 50 percent of the capacity is typically devoted to data formatting and error detection and correction requirements.

By comparison, a 2,400 foot reel of magnetic tape using high density encoding to achieve densities of 6,250 bpi in recording can hold 180MB of data. Magnetic tape sells for about $10 per reel, and tape has the advantages of being removable and interchangeable among many brands of drives. However, given the sequential nature of access to tape, a more valid comparison with the random access optical digital disk technology is magnetic disks. Magnetic disks using the Winchester technology of a hermetically sealed disk pack complete with read/write heads can accommodate up to 2.5GB of data (on the IBM Winchester 3380 system which utilizes two separate stacks of disks). However, unlike the lower capacity rigid magnetic disk systems (up to 300MB per disk pack), Winchester disks are not removable from their drives. Extra capacity can only be achieved by purchasing additional disk drives--an expensive undertaking. In contrast, the available optical media all utilize removable disks which can be purchased relatively inexpensively.

The optical media also pack information more densely than conventional computer storage devices: the track density of optical disks is between 10,000 and 20,000 tracks per inch, compared with 48 tracks per inch for floppy disks, and several hundred tracks per inch for rigid magnetic disks.

Speed of Data Recording

While it is always important that a data storage device be capable of recording data as fast as the unit which generates the output can produce it, the development of applications which generate immense amounts of data--oil exploration and satellite scanning, for instance--has emphasized the need for storage technologies capable of handling incoming data at very rapid speeds. The optical media offer the promise of higher write speeds than can be achieved by magnetic tape where speed is limited by the need for the read/write head to make physical contact with the recording surface. The optical media are slower than Winchester disks but have a cost advantage. Winchesters do not require physical contact between the recording head and the disk surface. However, the head is separated from the recording surface by a microscopically small space which is extremely vulnerable to contamination by dust, smoke particles, fingerprints etc. This sensitivity necessitates expensive controlled environment packaging. Optical systems obviate the need to engineer for such close tolerances in systems design.

NV Philips has achieved write rates of 10 megabits per second which compares favorably with the normal rate of recording onto magnetic tape--7 megabits a second. Faster write rates can be achieved in special applications. RCA has been working with the Rome Air Development Center to design and build a custom optical disk memory system capable of capturing the 10^{12} bits of information transmitted to the earth daily by the Landsat satellite. Ninety percent of this data is now lost due to the absence of a technology with sufficient

speed and capacity to accept the data. RCA expects to achieve a recording rate of 320 megabits per second.

Error Rates

In the computer industry the importance of the accuracy of data recording varies with the application for which the data is being collected. Accuracy is more important in systems which handle coded data than in those which store digitized image data.

Two types of error rates are frequently discussed: uncorrected or "raw" bit error rates and corrected bit error rates. The latter refers to the actual error rate experienced by a user once the storage system has performed the error detection and correction activities that it supports.

As the amount of data addressed by a typical system has grown, the permissible error rate has fallen. Current industry preferences call for corrected bit error rates of no more than 10^{-12} or 10^{-13}. As a result it has been necessary to introduce error management techniques into all classes of storage and communications equipment. Rigid media magnetic disk drives have intrinsic error rates of about 10^{-10} and the magnetic media for mainframe data applications usually provide corrected bit error rates of 10^{-13}. Not all magnetic media require this level of accuracy: floppy disks typically have a corrected bit error rate of 10^{-9}. For document storage applications where digitized images rather than coded data are recorded, a corrected bit error rate of 10^{-6}--one bit in error out of every one million bits--is thought to be more than adequate. An error in that range would show up as a tiny black speck on a high resolution image.

Typically, the intrinsic bit error rate of optical media is 1 in 10^{-6}--higher than that of the magnetic media. The optical media thus require more powerful error management strategies. Two basic error control techniques are used.

The first entails reading the data immediately after it is written and comparing it with the data input stream. In this "direct read after write" or DRAW* technique, errors are corrected by re-writing the data onto another part of the storage medium. In the second error management approach, error correcting codes are used to add redundancy to the input data stream to enable the data to be recovered even in the presence of very long error bursts.

In practice, error correction and detection techniques can reduce the bit error rate to 10^{-13} but these methods consume from 10 to 50 percent of the disk's total capacity. Storage Technology Corporation claims to be able to achieve a corrected bit error rate of 10^{-13} with an overhead of only 20 to 30 percent of disk capacity.

Speed of Data Access

In online applications, the speed with which a system can locate and retrieve data is also important. Access time is typically referenced in milliseconds (ms or msec). Most magnetic disk drives have an average access time of about 30 msec, considerably less than the projected 100 msec average access time of the optical digital disk. NV Philips has achieved seek rates of 75 milliseconds. This is, however, hundreds of times faster than the rate at which data on a magnetic tape can be accessed.

Archivability

Much of the discussion of the use of optical media for digital data storage centers on archivability--the length of time that data stored on a medium will remain stable without

* As initially introduced into the discussion of optical technologies, the terms "direct-read-after-write" and "DRAW" were used to describe this method of data validation. In more recent usage of the term, the original meaning appears to have been downgraded so that it is sometimes used merely to differentiate between technologies such as videodisc which require processing and mastering before the data on the medium can be accessed and optical digital media which do not require such processing. A reader can no longer be certain that a product described as using DRAW procedures actually compares the recorded data with the input data stream at the time of recording.

deterioration. The requirement for a highly sensitive surface for easy, rapid and dense data recording could be regarded as conflicting with the conditions required for archival stability. However, estimates based on laboratory tests suggest a life span for optical media of approximately 10 years. This compares with 2 to 3 years for information stored on magnetic tape. Data stored on tape has to be "refreshed" every two to three years by rewriting it onto new tapes.

Such archivability has yet to be proven in operational situations as optical storage systems have not been in place for that long. The pursuit of this elusive capability continues to be the focus of research. A number of companies are looking to the use of photographic recording techniques, hoping to ally the accepted 100 year life of photographic media with the data storage density of optical recording techniques. Research undertaken by Xerox using an optical medium of copper sulphate in glass yields a disk that some observers say could offer absolute archivability, perhaps lasting thousands of years.

In any case, the question is really one of economics. The disk appears to be performing well when compared with magnetic tape. And if deterioration occurs, the digital data can be read and written to a new disk or another medium. It only becomes a problem if the cost of monitoring and copying becomes prohibitive.

Ease of Handling

Unlike most high capacity magnetic media, optical media are readily removable from the drives on which they are written and accessed. Optical systems are also more robust, not being harmed by heat or humidity, magnetic fields nor surface pollutants such as fingerprints, hair or dust. The ease of handling makes it possible to develop automatic disk-

changing mechanisms similar to jukeboxes for optical disks. Some of the more ambitious designs posit jukeboxes of up to 500 disks each with a capacity of 4GB--offering the needy user online access to 2 million megabytes of online storage.

COSTS

As mentioned previously, the limited market penetration of optical storage systems makes informed calculations of the relative cost performance of optical media over traditional magnetic media difficult. The information presented in this section has been obtained from a variety of published reports and is offered to illustrate the range of cost advantages claimed for optical storage media.

Calculations by RCA cited in 1983 compared storage costs per online MB for various storage media. The figures included only hardware costs and resulted in the following comparisons: $150 for conventional tape drives, $40 for IBM's 3380 Winchester disk drives, $15 for a 4GB optical disk, and $5 for the 35GB IBM 3850 mass storage system which utilizes tape stored in cylindrical cartridges. At that time per MB costs for the purchase of top end storage systems were: for the three models of IBM's 3380 drive, from $28 to $39 per MB for 2.5GB; the 3850 offered $16 per MB for 35GB; and Masstor's M860 was $9 per MB for 50GB. While no unit prices had then been set for optical storage systems, the projections used costs of $50,000 per device with control units priced at $150,000 each. In that range a single disk of 4GB would cost a user $5 per MB. These estimates show the optical disk media costing only $.04 per MB compared with a high of $.84 per megabyte for the 3380 drives.

Estimates made in the same year for the application of optical technology for the storage of documents and images in a typical insurance company application with 22 to 50 million pages online in 2.5 million files posited that the necessary

optical disk hardware would cost $6 million, but that media costs would be less than $100,000 per year. It was expected that 25 to 30 percent of system cost would be for the optical hardware; the rest would be for computers, terminals and software. In such an application, the insurance company was expected to be able to recover its costs in three years through the increased productivity generated by the system.

OPTICAL DIGITAL DISK MARKETS

As detailed in the next chapter, markets for optical digital disk systems are generally perceived as belonging to one of two categories: general computer mass storage applications, and specialized document image retrieval systems. In the first area, the disk is in competition with the "traditional" magnetic media of disk and tape; in the second, with systems based on micrographics. There is a considerable amount of literature devoted to both battlefields. Overall, that devoted to the mass storage arena assumes co-existence of the different media and seeks to define the appropriate market niche for the optical technologies. By contrast, the literature on document and image storage and retrieval systems is a one-sided debate which reflects the defensive postion of micrographics proponents.

Optical digital disk systems offer cost advantages over magnetic disk and tape and access advantages over magnetic tape. The non-erasable nature of the optical disks is a two-edged sword: a disadvantage in applications requiring frequent updating of data; a clear advantage in other situations. The compact nature, transportability, and expected extensive lifespan of the optical disk technologies are of significance in some applications and irrelevant in others.

In general computer storage applications, there is a consensus that optical disk fills a major performance gap between magnetic tape and magnetic disk, but is not a replacement for either one.

Perceptions of the nature of the appropriate relationships among the media vary, but include the use of optical disk for magnetic disk back-up, long term archival data storage, and selective online storage of portions of files and types of data that do not require frequent amendment.

In specialized applications requiring the long-term storage of coded data or access to vast quantities of bit-mapped data, the medium appears to offer a unique amalgam of characteristics. These may prove to be of sufficient strength to support the implementation of systems which, while technically feasible, were too expensive to use before the advent of the optical storage technologies. Applications which fall into this category are detailed in chapters 9 and 12. The long-term viability of these prototype systems is dependent upon the emerging media price and performance parameters that are being tested in these applications.

A similar situation may also develop in relation to document storage systems. The technology's ability to accommodate various types of machine-readable data--character coded and bit-mapped--and the emergence of favorable cost structures vis-a-vis the sophisticated micrographics systems required to support similar capabilities, could provide optical technologies with an edge in this market.

TECHNOLOGY

In the long run, the details of the composition of optical media will matter little to most users; the media along with the associated hardware and software will have to be transparent to the user to gain wide market acceptance. However, in the initial stages of discussion of a new technology, some background is essential for an appreciation of the potential of the technology and for the relative assessment of marketing developments vis-a-vis established technologies. The essential elements of optical digital disk technology are

discussed in the following pages. Caveat emptor: the technology is still in the development phase, development is rapid and, in some cases, closely guarded. Therefore it should not be assumed that the information presented here is either comprehensive or up to date. A number of companies known to be actively pursuing the optical digital technology were unwilling to detail either the extent or direction of their interest.

The features which differentiate an optical disk storage system from a magnetic-based drive are the optical read/write heads and the write once optical media. The other major components of floppy or Winchester drives are functionally similar to those used in optical disk drives.

Optical Read/Write Heads

The products of different manufacturers use different systems for reading and writing on optical storage media. The majority of systems currently under development use one or another form of laser for data recording and reading. Whereas read only videodiscs and compact audio discs are usually pressed from masters in quantity, optical digital disks are each written individually on an optical disk drive. Current applications are such that an optical digital disk on which data has been recorded is not readily replicable; copies of a written disk can only be made sequentially by reading from a disk and writing to another disk. This approach is not inherent to the medium. Techniques similar to those used in the replication of videodiscs could be used to mass produce optical digital disks encoded with digital data. The reason this is not done is that the applications for which the technology is being developed do not demand the mass replication of the data encoded on the disks.

The design of optical recording media allows the use of optical read/write heads capable of high performance when positioned 1 to 2 millimeters from the disk surface. The disk

recording surface is protected by a layer of clear material which permits unobstructed passage of the read and write beam without concern for interference from dust or other debris on the disk surface.

These features allow optical storage systems to be designed with removable disks without the implementation of expensive sealed cartridge systems or air purging cycles. The disk only requires a plastic cartridge for storage when not on the drive to prevent excessive damage during handling.

To write on a disk the drive focuses the laser beam on the sensitive recording layer. The write beam is turned on and off in a sequence which reflects the digital nature of the data. In write mode, information/non-information is recorded according to whether the laser is on or off during an instant. In some systems, the write laser also performs the read function--writing is undertaken in high-intensity power load, reading in low power mode with a continuous light output. Other systems utilize separate lasers to read and write, while still others use separate drives for reading and writing, sometimes requiring processing of the recording medium to "set" the information before it can be read.

In reading, the difference in reflectivity between an unwritten area and a written spot causes an amplitude modulation in the reflected read signal which is detected and decoded in the read channel.

Currently, the optical disk systems which appear to be achieving the best performance use a Direct-Read-After-Write (DRAW) approach to data recording. During recording, writing is immediately followed by reading to check the accuracy of the recorded data.

In contrast to the video-based formats used in recording videodiscs, both optical digital disks and compact audio discs

are being developed as devices for storing digital data, a format which requires no compatibility with video signals or formats. The ability to read the data as they are recorded allows the immediate identification of errors.

Errors detected during the DRAW process are "corrected" by rewriting the data in a new sector of the disk and erasing the address of the "bad" data from the index to the disk. Information is not erased from the disk but, rather, the knowledge of the locations of the information is made unreadable. Using DRAW techniques, user information stored on an optical medium can be recorded with a very low error rate.

The Optical Storage Medium

Many of the materials and techniques used in optical digital media are similar to those used in the production of master discs for optical videodisc production. All are "optical" in that they rely on the use of materials which are affected in some way by the application of light. In most, the alteration of state caused by the light source during the "write" process can be detected by differences in the way in which the affected and unaffected parts of a recording surface later respond to the application of a "read" light. Some of the materials used in the recording media are sensitive to the heat generated by a laser light source and respond to its application by melting, revealing an undercoating with different reflectivity characteristics. In other processes the application of heat in the form of light causes the formation of gaseous bubbles, the presence of which can also be detected by optical techniques. Another group of approaches utilizes dyes which are affected by the application of light. The more commonly referenced technologies for the preparation of the optical media used for digital data recording are discussed in the following paragraphs. Related techniques being pursued in the search for an optical recording medium capable of being erased and reused are discussed in chapter 10.

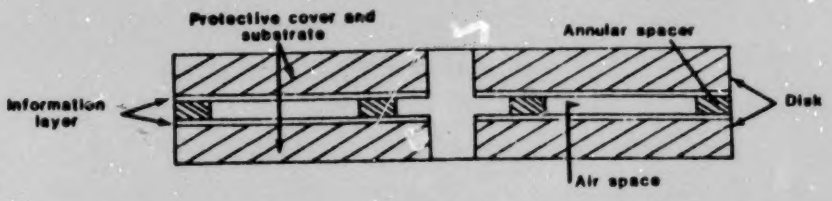
A common technique involves the deposition of a thin layer or film of heat sensitive material on a metal, plastic or glass substrate. Most work in this area has concentrated on the use of tellurium or a mixture of this and other materials as the recording surface. A particularly attractive feature of tellurium is its low thermal conductivity and fine recording resolution. However, pure tellurium is subject to rapid oxidation and degradation by humidity and has a tendency to flake off the substrate on which it is deposited. Therefore, most applications utilize mixtures of tellurium and other materials and a number of methods have been developed to protect tellurium surfaces from oxidation. These include encapsulation, overcoating, use of layered structures and use of the air sandwich structure developed by Philips. Research has also been undertaken to identify viable alternatives to tellurium. Among those which appear promising are silver halide, and gold/platinum alloys.

The toxicity of tellurium has raised some concerns, but the practical effects of this toxicity are debatable. Of greater import to producers is the possibility that the declaration of tellurium as a toxic substance could result in handling regulations that would make its use prohibitively expensive.

Products under development by Control Data Corporation, Fujitsu, Hitachi, Matsushita, Omex, Philips, RCA, Storage Technology, Toshiba and Xerox all utilize tellurium-based materials. Thomson-CSF in cooperation with Xerox's Shugart Division uses a gold alloy, and silver halide particles are used in the Drexon technology. In Drexon products, the recording material is suspended in an acrylic medium rather than being deposited in a thin film or layer.

A variety of methods have been developed to achieve a disk structure that will protect the recording medium. Other

work focuses on creation of alloys which have a greater degree of stability than tellurium. Two major tellurium disk programs--at Philips and RCA--appear to be concentrating on protecting the tellurium medium rather than altering its composition. In the Philips "air sandwich," two glass or plastic disks, each with a film of tellurium on the inner side, are separated by inner and outer circular spacers. The cavity between the disks and spacers is filled with "clean" air and hermetically sealed to protect the tellurium from deterioration.



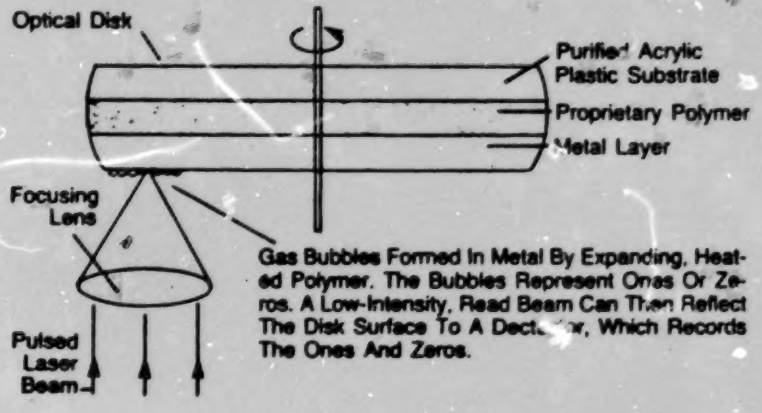
Cross section of Philips
"air sandwich" disk

Source: Charles M. Goldstein. "Optical Disk Technology and Information," Science, 12 February 1982, Vol. 215, p. 864.

It is claimed that the process will protect the tellurium layer for at least ten years. Data is recorded on such disks using a relatively high-powered laser beam that focuses through the protective surface and burns the information on the tellurium surface. The data can be read immediately after it is recorded.

RCA places the tellurium on the "top" surface of a substrate and uses a plastic overcoating to protect the medium; no claims are made, but the company "hopes" the protected tellurium will have a life of 5 to 10 years. To record data on the medium a write beam is passed through the tellurium and through a transparent film to expose a reflective aluminum layer laid on a substrate. The light bounces back and forth between the aluminum and the tellurium until the energy is absorbed, heating the tellurium and creating a pit. The disk is encased in a protective plastic overcoat.

Another approach is to use a laser to create tiny bubbles in a thin metal surface. Because the metal does not have to be vaporized, it can have a higher melting point than the materials used in systems which rely on the burning of pits in a surface. Materials with a higher melting point are inherently more stable than those with low melting points. The Shugart Optimem system uses this approach in a disk in which a substrate is coated with a decomposable polymer which generates gaseous products when heated. The polymer is topped with a metallic layer. The heat of a laser in write mode is transferred through the metal to the polymer. Heat causes decomposition of the polymer and the resulting gases form a permanent bubble in the metallic layer.


Optical Disk
Purified Acrylic Plastic Substrate
Proprietary Polymer
Metal Layer
Focusing Lens
Gas Bubbles Formed In Metal By Expanding, Heated Polymer. The Bubbles Represent Ones Or Zeros. A Low-Intensity, Read Beam Can Then Reflect The Disk Surface To A Detector, Which Records The Ones And Zeros.
Pulsed Laser Beam

Source: Paul L. Young. "Vendors Gamble on Optical Disk Storage R + D," Information Systems News, January 24 1983, p. 30.

The Drexler Technology Corporation manufactures Drexon, a proprietary optical material which uses special high resolution photographic emulsions. During the recording process, the photographic emulsion is formed into a crust and an underlayer. The mirror-like appearance of the crust is created by a high-volume concentration of reflective nonfilamentary silver in a gelatin matrix. The underlayer contains a moderate-volume concentration of black filamentary silver in the gelatin matrix, creating a dark appearance. The dark

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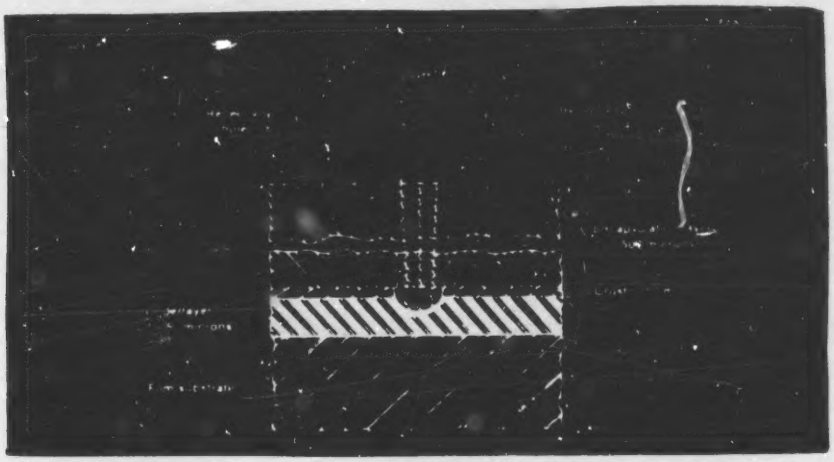
underlayer increases recording sensitivity by enhancing laser energy absorption and thermal insulation. During recording, the laser melts and shrinks the gelatin matrix, forming pits. This allows the use of low powered lasers. Data is read using a photodetector array which measures changes in the reflected light caused by the absence or presence of recorded pits.



Structure of Drexon Recording Material
Source: Drexler Technology Corporation

Because the raw materials used to make Drexon products--disks, cards, or tape--are photographic films, copies can be made using photolithographic techniques. This pre-recording technique can also be used to preformat blank disks with timing marks, tracks, and sector information.

Drexon has a projected life span of ten years and, allegedly, a better uncorrected error rate than other types of optical media. Claims of an uncorrected bit error rate of 10^{-7}, at least 100 times better than those reported for tellurium-based media, have been made. Drexon disks should thus require less error correction. What is sacrificed is storage density. The disks have approximately one-fifth of the capacity of the disks Philips and RCA are developing.

Several companies, including Kodak, are exploring the development of recording media which use organic dyes held in

very high concentrations in a polymer binder. This technology uses processes similar to those for the manufacture of silver-halide photographic film. The dye and a polymer binder are solvent coated onto a substrate to produce an amorphous layer of high optical quality. The dye absorbs light of specific wavelengths. The dye polymer media show better sensitivity and signal quality than thin metal film media, but there is some question as to their longevity. The use of lasers with different wavelengths for recording and reading data avoids the danger that reading will overwrite the data on the disk. The technology is not without its problems however. The dye used in some Kodak research has an absorption band in the blue-green region, which is accessible only by relatively large and expensive lasers. Capacity on a 12 inch Kodak disk is reportedly 5.6GB per side. Similar media responsive to more readily accessible infrared lasers have been investigated by IBM.

Just as there is diversity in the materials used as recording media in optical technologies, so too is there debate over the choice of an appropriate substrate on which to base the recording surface. Aluminum can react with some of the recording media and may be subject to deformation; glass is fragile and expensive; and plastic may warp over time. For tellurium-based products produced using the air sandwich configuration, plastic also appears to allow some seepage of humidity which degrades the recording surface. Several major disk producers are rumored to be changing from plastic disk substrates to glass.

Non-Disk Media

The media and recording techniques that are being developed for use in optical digital disk systems can also be applied in other formats such as card, tape and slides. Omex is developing a data storage and retrieval system which utilizes optical technologies to read and write data stored on a

tellurium surface in a glass sandwich constructed in the form of rectangular slides.

The medium developed by Drexler for optical disks has also been produced in card and tape formats. The format currently receiving the most attention is based on the standard plastic credit card. In the Drexon Laser Card the magnetic stripe usually found on the back of a credit card is replaced with a strip of optical material with a storage capacity of 1 MB. Cards are also available in a 2 MB format and it is thought that double-sided cards might offer 5 to 10 MB of storage.

Laser Cards are being developed for a number of applications. For software and data base publishing the cards can be pre-recorded economically: in quantities of 100,000, Laser Cards containing 1 MB of data cost $1.50 each; the 2 MB format costs approximately $6.00 per card. Laser Card readers being developed by companies such as SRI International are also expected to be inexpensive--around $100 per unit. While data cannot be erased from the cards, or rewritten, it can be added. Read-write devices for adding data to Laser Cards are expected to cost around $500.

The storage capacity and security offered by the non-erasable medium are attracting attention for use in the banking, health insurance and medical records fields. Other personal identification applications might include passports and drivers licences. As with other optical digital storage devices, the card can be encoded with any form of digital data--character encoded alphanumerics, digitized sound and digitized graphic images.

Disk Formatting

The density at which data tracks can be recorded on optical storage media requires the use of a track guidance system

to facilitate data reading and writing. In expensive high performance disks this is accomplished by servo writing, a process in which the track guidance pattern is written on the blank disk by the laser in the disk drive prior to the recording of digital data. Recording of such control and guidance data at the user site requires the use of disk drives with precise and sophisticated, and therefore expensive, components. Other processes which can be carried out during this formatting operation include checking the disk for defects, writing sensitivity, and mechanical parameters.

In lower cost applications the usual approach is to mold or "print" the guidance pattern on the optical digital disk during the disk manufacturing process. Disks prepared in this way are described as pregrooved, and do not receive the extensive quality control checking possible when a blank disk is individually formatted. Nor, however, do they require the use of sophisticated and expensive recording units or drives.

In digital optical recording, the pregrooved process can be used to provide radial servo track feedback and data synchronization. It can also be preformatted to provide head positioning feedback. In this way, the precision required to achieve high areal recording density is put onto the disk instead of into the disk drive. Preformatting of the disk is inexpensive, whereas preformatting on a drive takes up to half an hour per disk. Early optical digital disk projects used disks which were not preformatted. Later developments appear to suggest that such preparation is essential if efficient data storage and retrieval is to be achieved. Some data storage capacity is lost in the pregrooving process.

The manufacturing process for producing blank preformatted optical disks is similar to that used to produce a reflective optical videodisc or a compact audio disc. It starts with a polished master disk coated with a photo-resist

material. The resist coated disk is written on a mastering station using a laser and copies are produced through stamping or molding. It appears that the key to successful implementation of low-cost laser optical disk systems is the availability of low-cost media which can be manufactured with servo, address and synchronization information on the disk.

Meanwhile, Magnetic Media Rise to the Challenge

Whereas the early discussions of optical data storage technologies focused solely on the apparently unlimited potential of such media, more recent commentaries have tended to combine discussions of the potential of optical digital recording with surveys of the advances being made in traditional magnetic recording technologies. Given the delays in the appearance and acceptance of optical storage systems, such a shift in focus is not surprising. One such recent survey is Charles M. Goldstein's "Computer-Based Information Storage Technologies" which appears as chapter 3 in the Annual Review of Information Science and Technology, Volume 19.

CHAPTER 9. OPTICAL DIGITAL PRODUCTS

The optical digital disk was first demonstrated by NV Philips in 1978. Since that time, the literature has been full of enthusiastic predictions of the promise of the technology for use in computer centers, libraries, offices and a myriad of other applications. Even allowing for the fact that the diffusion rate of new technologies is slow in almost all applications—typically 10 to 15 years from development to widespread use--the short history of the optical digital disk has been a continuing chimera of product announcements made months or years in advance of actual system availability. As of early 1985, none of the applications of the technology appeared to have become established in North America. Not only are there insufficient systems for a realistic assessment of the performance of the technology, such products as are available continue to undergo significant changes as manufacturers search for techniques that will support the promised levels of system performance.

Prior to 1984, the U.S. systems based on these technologies were basically laboratory prototypes or one-off custom configurations. During 1984, a number of products became available. Observers report that there are some 32 firms researching and developing optical drives worldwide, and that 54 organizations are working on optical media.

Currently, the products fall into two main application categories: computer mass storage peripherals of large (4GB) or moderate (1GB) capacity, and turnkey document and image storage systems. System integrators are beginning to configure the available optical storage devices into special function systems targeted at markets such as medical records management. Commentators are predicting the imminent availability of two other products: small size, low cost, 5-1/4 inch write once optical digital storage devices for micro-

computers,and low cost document storage systems. The emergence of products based on the erasable optical digital disks discussed in chapter 10 is also forecast, but such systems are not expected to be commercially available before late 1985 or 1986.

Although a number of optical disk products are now "available," their penetration of the North American market has not yet been sufficient to allow informed assessment of operational performance. Nor does it seem that the technology has been embraced as enthusiastically as most producers and observers expected.

In addition to classification by application, current products may also be classified by size--large scale mass storage systems and those designed for smaller applications. In the first category is Storage Technology's Model 7600 Optical Storage Subsystem with a capacity of 4GB on a 14 inch removable disk; in the second are products from the Shugart Corp. (the Optimem 1000), Thomson-CSF Inc. (the Gigadisc GD 1001) and Philips' Megadoc System. Each provides 1 GB of storage per 12 inch disk, and all are targeted for mini- or microcomputer-based office applications. Both Thomson and Philips also offer jukebox configurations to permit online access to up to 100 disks in one system.

Closely related are the document storage systems being offered by several Japanese companies. The error rates being achieved in the optical disks used in these systems are such that most are currently limited to the storage of the digitized results of image scanning processes rather than computer-searchable data. Most systems are capable of supporting only a single user station. Systems recently announced by Hitachi and Cannon have better error detection and correction capabilities and thus can also be used for storing character coded data.

Large Capacity

One company in the U.S. is actively marketing an optical digital disk system that approaches the storage capacities predicted for the medium. Storage Technology Corporation's 7600 Optical Storage Subsystem is based on the 7640 Optical Storage Unit which offers 4 GB of online storage capability on each removable 7440 Optical Media Unit platter. The platters (disks) are encased in rigid plastic cartridges when not mounted on the drive.

The single-sided 14 inch 7440 Optical Media Unit platters consist of an aluminum substrate which is covered by a layer of tellurium-based material sensitive to a laser write beam. Each platter is preformatted into 716 concentric data bands. Servo information is encoded on the platter during manufacture using a laser recording technique rather than a grooved technology.

The drive contains two lasers--one to write data, another to read it, and data is recorded using the direct-read-after-write approach. The system offers an average access time of 85 milliseconds for any record on the disk surface; the maximum access time is 149 milliseconds. The recording medium has a projected life-span of ten years. The system supports a raw bit error rate of 10^{-5} and a corrected bit error rate of 10^{-13}.

The 8880 Storage Control Unit combined with optical storage access method (OPSAM) software allows a host CPU to write and retrieve data from the optical storage system. The controller is compatible with IBM processors running under the MVS/SP 1.3 operating systems. The controller is the same device used by the company to control its magnetic disk drives and can handle multiple optical disk drives.

The 7640 Optical Storage Unit has a list price of $130,000. The 7440 optical platters are priced from $140 to $225 each, depending on quantity. The control software costs $1,000 plus a monthly fee of $400.

Other companies are also working on high capacity systems, but in a custom-only mode. Many of the upper estimates of optical disk capacity and capabilities are based on reports of such work. RCA is one such company. For instance, it uses techniques such as 10 simultaneous write heads to achieve spectactular recording speeds of up to 500 megabits per second.

Lower Capacity

Most U.S. implementations of the optical digital disk as a computer storage peripheral are focused on the use of lower capacity devices capable of storing around 1GB of user data. Shugart and Thomson-CSF offer common products in this category, and Maxwell and Hitachi recently announced the availability of disks using a different technology.

These currently appear to be the only optical digital disk products which adhere to a standard--the Small Computer System Interface (SCSI)--initially developed by Shugart. SCSI is being adopted by the American National Standards Institute (ANSI). Such interfaces transfer command and status information between the host computer system and the peripheral storage devices. Using such an interface in optical disk drives makes it possible to design an optical disk controller with the same host-to-controller physical interface that is used by other peripherals such as floppy disks, Winchester disks, streaming tape drives or printers. This facilitates the integration of optical disk drives into existing computer systems. The system integrator has only to be concerned with the development of the software to interface the applications program to the optical disk. In systems which do not use such

an interface, the lack of controlling software is a major restraining factor in the penetration of the optical storage technology. There may be some problems in converting control software from erasable magnetic media to write-once optical media. To succeed in the market, optical disk producers will need to ensure the development of control and interface software compatible with the installed base of computers from major vendors.

SCSI includes a group of six generic commands which, once implemented into the host operating system, achieve device independence by allowing system integrators to upgrade rotating memory peripherals and other devices without designing a new controller or changing the operating system peripheral driver software. It also provides a logical block address interface which passes error correction data back to the host. With SCSI, all housekeeping operations including error detection and correction, formatting, data separation, data buffering, etc., are transparent to the host processor. Similar interfaces, but possibly less sophisticated, are required to facilitate the use of CD ROM products in computer systems.

ANSI is investigating the development of standards in other areas of optical digital disk technology. One committee is working on the standardization of unrecorded optical media for the five sizes of optical digital disk currently under development--8, 12, 4.72, 14 and 5.25 inches.

Shugart Corporation, a Xerox subsidiary, offers the Optimem 1000 optical digital disk system with a storage capacity of 1 GB per disk side. The system uses 12 inch removable disks which are available in one-sided (Optimem 1001) or double sided (Optimem 1002) format. The disks are protected by a plastic cartridge when not mounted on the disk drive.

Each disk side contains 40,000 tracks, each formatted into 25 sectors. Each sector has a capacity of 1,024 bytes. Average access time is 130 msecs with a maximum access time of 230 msec. The disk is pregrooved and preformatted with sector address information. It is recorded at the user site but does not use the direct read after write method of error detection.

The Optimum 1000 Optical Disk Drive is compact, measuring 16.6 inches wide by 24 inches deep and 6.81 inches high. It weighs 50 lbs. The drive is microprocessor controlled and utilizes the Small Computer System Interface. The system can accommodate up to eight drives per controller. The Optimem disk drive with SCSI interface gives corrected error rates of no more than 1 error in 10^{12} bits transferred. The drive costs $6,000 not including the controller.

The system uses a plastic disk coated with a metallic layer over a decomposable polymer which generates gaseous products when heated. The heat of the laser in write mode is transferred through the metal layer causing decomposition in the polymer and the formation of a bubble. Once the laser energy is removed a permanent bubble remains on the recording layer. This is read by the same laser operated in a low-power mode.

Shugart has a joint development agreement with Thomson-CSF and uses its technology.

Thomson-CSF offers the Gigadisc GD 1001 optical disk system which is apparently identical to the product marketed by Shugart. The system is capable of storing 1GB on one side of a 12 inch disk. The system uses the SCSI interface and a controller capable of handling up to eight drives. Corrected error rates of 10^{-12} are claimed. Publicity material indicates that "a recorded disk can be physically copied by a physio-chemical process," but no equipment is offered to

support this operation. The disk drive is available in two different "packages": rack-mounted (the GD 1001/10) or standalone (GD 1001/20).

As of late 1984 at least one company had announced plans to offer a Shugart-based commercial product as part of its microcomputer peripheral line. National Memory Systems Corporation of Livermore, CA is promoting its PC-007 Series laser optical disk for use with Texas Instruments and IBM PC microcomputers. National Memory System's configuration includes the Optimem 1000 drive and optical disk, and a proprietary controller and software. The system utilizes the SCSI interface which can accommodate up to eight optical disk drives. The units, scheduled to be available in December 1984 with a delivery time of 90 to 120 days, are priced at $19,900 in single quantities with disks priced at $350 each. Advance publicity promises storage capacity of 1GB and an average access time of 100 msec with a maximum access time of 200 msec. The unit is said to have an error rate of 10^{-12} and a seek error rate of 10^{-6}.

The Maxwell Corporation of America, a joint development of Hitachi and Maxwell Hitachi of Japan offers the Maxwell Optical Disk Cartridge for optical recording. The 12 inch disks, available in one or two-sided format, consist of a tellurium derivative mounted on a glass substrate in an air sandwich configuration. Data is encoded through the laser production of pits in the sensitive surface. The disks are pregrooved and have a data recording capacity of 1.3GB per side. One-sided disks are priced at $200, two-sided disks cost $300. Hitachi also markets the disks and has developed associated hardware for a full disk storage system. The 301 Optical Disk Subsystem is said to achieve corrected error rates of 10^{-12}, permitting storage of both image and encoded data. Access time is reported as a quarter of a second. The system is available in two configurations. The basic configu-

ration provides a controller capable of supporting up to four optical disk drives; the "library" configuration has a jukebox capable of handling 16 disks per drive on one or two drives. In this configuration the controller and an automatic disk changer are part of the "library" unit.

Although not yet available on the open commercial market, North American Philips manufactures a 12 inch double sided disk using its air sandwich structure. The disk has a capacity of 1.4GB per disk surface. Errors are corrected to 10^{-9} with 40 to 50 percent overhead for formatting and error correction and detection. The disks can support corrected bit error rates of 10^{-12} at the expense of capacity. The raw bit error rate of uncorrected disks is 10^{-6}.

North American Philips uses a plastic substrate for its disk product whereas N.V. Philips in Holland uses glass in its version of the air sandwich. It is thought that the glass substrate might provide better archival performance as plastic transpires water, a condition known to be deleterious to the tellurium used in the disks. Despite this potential problem, North American Philips projects an archival life of 10 years for its disks. Shugart and Thomson are apparently also encountering disk substrate problems and are in the process of changing from a plastic to a glass substrate.

The Philips disks are written using diode lasers, generally in spiral patterns. The disks are read with helium/ neon gas lasers. The North American Philips disks are apparently not pregrooved, whereas the Dutch disks are, simplifying the recording process at the expense of capacity.

N.V. Philips and Control Data Corporation have formed a joint venture--Optical Storage International--to design, manufacture and market optical recording peripherals and media for use with computers. A sample drive, the LaserDrive 1200, has

been displayed and indications are that it will be priced between $6,000 and $[illegible]0. The drive includes a controller. Single sided media will cost $200 to $300 initially and double sided disks will be offered.

OFFICE/DOCUMENT STORAGE SYSTEMS

A number of companies are configuring turnkey systems based on optical digital disks for office filing and document storage applications. Some of the earlier systems utilize lower performance disks more suited for the storage of digitized image data than for recorded character encoded digital data.

Megadoc

In April 1984, Philips demonstrated its much heralded Megadoc system for the first time in the United States. The system provides archival storage for digitized images of documents. It can accommodate any material that may appear on an 8-1/2 x 11 inch page--print, manuscript, typescript or photocopy. It also accommodates data input by keyboarding or transfer from a computer system.

Philips offers Megadoc as a turnkey system comprising hardware, software and support in setup and implementation. The basic system configuration includes a mini- or microcomputer, a document scanner, one megabyte of disk based magnetic storage, workstations with regular and high resolution screens, an optical disk drive and a high resolution laser printer. Although not offered as part of the Megadoc system, contracts can be arranged for configurations which include a microform input scanner. The regular Megadoc system will accept input from other sources including keyboarded data, data from magnetic tape and disk, and data from remote facsimile units transmitted over telecommunications lines.

The images of documents to be stored in the system are input through the scanner which provides scanning capabilities

of 200 lines per inch. The scanner is capable of operating at 300 lines per inch, but this option has not yet been made operational. An automatic feed device permits the scanner to process page input at one page in three seconds. The digitized data from this process are stored on magnetic media pending operator review. The operator recalls the document image on the high resolution viewing screen to check that input has been effective and to assign any required indexing and retrieval information. Once the validity of this data is verified, it is passed to the optical disk drive for recording on the disk.

Data can be output from the system in a number of ways. While the basic Megadoc configuration includes the high resolution screens already mentioned, it also supports a laser printer capable of producing hardcopy of the document images at a speed of one page in three seconds, at 200 lines per inch resolution. Data may also be output to magnetic tape or disk storage. A single Megadoc system can handle up to 32 simultaneous users. Magnetic storage is used as a holding station when outputting data, freeing the optical drive to access and retrieve information in response to the needs of other users.

The recording material used on the optical disks is tellurium. The disks are produced by joining two glass platter coated with tellurium. The platters are separated by spacers and the gap between them is filled with "clean air" before being hermetically sealed. The tellurium coated surfaces are on the inside of this air sandwich, and thus are protected from environmental contamination.

The disk is mounted in a recorder/player connected to a computer, typically a minicomputer or mainframe. A high-powered laser beam is focused through the protective surface of the disk, burning the information into its surface. The recording system uses the direct read after write approach

which enables errors to be identified immediately after data have been written. Errors are corrected by rewriting the data in a new sector on the disk. The address of the "bad" sector is erased from the computer memory. Thus, the incorrect data are not erased, but the computer no longer has a memory of that sector. A Philips spokesperson has indicated that corrected bit error rates do not exceed 10^{-12}, an occurrence equivalent to one error in every 100 disk surfaces.

The disks are preformatted to allow random recording of information to any of the addressable sectors. The disk has the equivalent of 45,000 usable tracks and is divided into 128 sectors. Each sector/track combination is given an individual segment address, thus allowing the segments to be located in a random access mode.

A document image can be retrieved in no more than three seconds from a mounted disk surface. If data on the flip side of a disk needs to be accessed, the disk must be removed and turned manually. Similarly, simple system configurations require that multiple disks be loaded and unloaded manually.

The Megadoc system can also be configured with a jukebox device capable of storing and handling 64 optical disks. In the jukebox configuration, location and mounting of the required disk for recording or reading is handled automatically as is the turning of a disk when there is a need to access information recorded on the flip side of the platter. In a non-jukebox system, such operations have to be performed manually. A single Megadoc system may be configured with up to three of these jukebox mechanisms. Philips indicates that access to any record stored in a jukebox system can be achieved in no more than 18 seconds.

The price of a Megadoc system depends on the actual configuration of the system chosen. At a presentation in

November 1984, a Philips spokesperson indicated that a system comprising two workstations--with both regular and high resolution displays, and keyboards--one CPU, a document scanner, magnetic storage, two optical disks drives, and a high speed printer would cost in the region of $400,000. The price is expected to drop in the future as more systems are installed.

As of November 1984, Philips was thought to be still searching for a beta test site in the United States, and not yet to have sold any systems in North America. [When the system was first shown in the U.S. in April 1984, a company spokesperson indicated that four Megadoc systems would be installed by the end of the year, and that sales in the first 12 months would be about 100 systems.] The company is believed to have seven systems installed or contracted for in Europe.

In promoting Megadoc, Philips quotes storage capacities of one side of an optical disk as being equivalent to the output of a single data entry operator inputting data for 35 years (500,000 pages per disk side at 2,400 bytes of data per typed or keyboarded page). Cost comparisons with other media --excluding the cost of the hardware--suggest that one jukebox unit can store the same number of document images that would cost $253,000 on 48X reduction microfiche for only $64,000.

Philips indicates that Megadoc systems can be installed within six months of the placement of an order. The delay is supposedly due to the turnkey nature of the installation which includes systems design support in setting up appropriate indexing and file management procedures.

FileNet

Optical Storage International disks are the basis for the Optical Storage and Retrieval (OSAR) system developed by FileNet Corporation of Costa Mesa. Demonstrated in October

1984, the FileNet system is intended for office document storage and retrieval. The system also provides integrated data base management, word processing and communications capabilities. The system can communicate with IBM mainframes. It is scheduled to be marketed January 1985 at a cost of $250,000 for an entry level system. The base configuration includes a scanner, three supermicrocomputer-based servers, two display stations, a laser printer, an optical storage and retrieval library and an Ethernet-based local area network. Each library unit can store up to 64 optical disks and may have up to four optical disk drives. The double-sided disks have a capacity of 1GB per side. The disks, manufactured by Optical Storage International, cost $400 each. The drives are manufactured by Hitachi. The first installation will be in the Security Pacific National Bank of Los Angeles.

The software includes windowing which would, for example, allow a user to call up an original document such as a check or a letter, start a word processing file in another window and in a third window call up a document from an IBM mainframe. Documents that have been stored on optical disk can be annotated; the system then logically links the two storage locations on the disk so that when a user calls up one portion the other appears as well.

Toshiba

The Toshiba DF-2000 was first shown in 1980 and evolved into the DF-2100 document image digitalization, storage and retrieval system for office applications. About 300 have been delivered in Japan since their release there in 1982. It was not possible to determine the current level of U.S. sales, but these are thought to be low. The system includes a scanner, optical disk drive, and a high resolution CRT workstation with a laser printer and a microprocessor controlled keyboard. The 12 inch optical disk stores 900MB with a corrected bit error rate of 10^{-7}—too high an error rate for applications other

than the storage of digitized facsimile images. A disk is capable of storing the images of 100,000 document pages. Input and hardcopy output are at 200 x 200 lines per inch, and the system supports screen display at 100 x 100 with a zoom feature for close-up viewing of fine detail. The unit can scan a page, digitize the page image, and record the data on disk in less than four seconds per page. A page can be retrieved and displayed on the monitor in 4 seconds, or printed in 14 seconds. It is a single user system and sells for about $55,000 in Japan. The U.S. price is around $120,000 with disks priced at $140 each.

Panafile

The Panasonic product line includes two different technologies; one is similar to videodisc, the other uses optical digital disk. The videodisc-related products record data in the NTSC format; the optical digital disk products record data in direct digital form. This latter technology is the basis for the Panafile Document Storage System released in the U.S. in October 1983. (The videodisc-supported sytems are described in chapter 5.)

The Panafile Document Storage System consists of a CPU, an optical storage unit, a high resolution monitor, an input scanner and a printer. The index registration system is stored on floppy disks, but the index key words and document number are written on the optical disk. The system supports access by only one user at a time. Five percent of the disk is devoted to storing the index information. Input documents are scanned at a resolution of 200 lines per inch, and the scanner can process up to 30 pages a minute. The system can also support processing at 400 lines per inch. Stored documents can be printed in five seconds. Images may be enlarged for display or printing. The Panafile system is priced between $70,000 and $100,000 depending on capabilities and configuration.

The Digital Optical Memory Disk Recorder which forms the heart of the Panafile system records data on 8 inch optical disks. The recording medium is tellurium, and the disks are pregrooved to facilitate data recording and retrieval. Data is recorded and read using a single laser. Each disk surface provides 700MB of usable data storage. The disks have an uncorrected error rate of 10^{-5} which is reduced to 10^{-7} after correction. Recognizing that such error rates are too high for machine-readable data applications, the company promotes the technology for use in image processing and document storage applications.

If linked to a communicating terminal, Panafile can be used to send data to remote locations. It will also accept input from telefacsimile units, and if linked with an x-ray unit, may be used to store x-ray images.

Other Document Storage Systems

Hitachi, Sharp, Sanyo, and Mitsubishi have shown similar systems in prototype. A prototype by Canon suggests unusually high performance and capability. Expected to be priced at $44,000, the system offers an optical disk store for 1.3GB of data on a 12 inch plastic disk, or 500MB on an 8 inch disk. It also includes an input scanner of 400 x 400, a 1200 line CRT display, a 400 x 400 laser printer with 30 sheets per minute and half tone capabilities, a scanner and automatic handler for reel microfilm, and an electrophotographic display capable of 400 x 400 resolution produced in 4 seconds. A proprietary local area network allows multiple output devices to communicate with each other and with the optical disk.

Image Resources Inc. of Winter Park, FL uses the Panasonic Optical Memory Disk in its Medical Storage and Retrieval (MEDSAR) system. MEDSAR contains a built-in character generator (keyboard) allowing the operator to record additional information on the image. The system's built-in Screen Writer functions like a computerized pen and allows the system operator to draw, write notations, or identify existing

images by writing freehand directly onto the screen. In addition, MEDSAR offers hard copy and CRT output. Options include a high-resolution, large format printer, multi-station access, customized computer programs, color imaging, light table for image recording, and a color or black and white imaging camera.

Related Products

In the classification of videodisc technologies presented in chapter 2, mention was made of photographic film-based optical videodisc systems thought to be under development by several companies. It has not been possible to elicit detailed information on these systems--although some "expectations" are presented in chapter 12 in a description of work being undertaken by the National Air and Space Museum--and their mention in the videodisc section of this report is a result of the categorization applied by commentators when such developments first came to light several years ago. It now seems probable that product development will be aimed at the optical disk market. In a research announcement late in 1984, Kodak indicated that it is developing a 14 inch optical disk which will use photographic techniques to store up to 100,000 standard page images per side on a two-sided disk. Product development will be targeted at office automation applications. The development of film-based systems could have considerable appeal in archival applications given the recognized archival characteristics of silver halide film stock.

The Mnemos System 6000 described in the following paragraphs does not use photographic technologies and is not normally classified as an optical digital disk system nor, since it does not utilize the television video format or support sound or motion playback, as a videodisc system. However it "should" be classified, the system description is included to indicate something of the direction of known developments.

The Mnemos System 6000 records microminiature "photographs" of documents on MnemoDiscs, 12 inch flexible plastic

disks. The disks are produced by replication from a glass master which is embossed with image and digital data in a clean room mastering and replication facility. Thermoplastic copies are pressed off the master. Each disk can store the images of up to 6,000 8-1/2 x 11 inch pages. The page images are recorded at a resolution of 200 lines per inch at 1/88th of their full size. The images look like microform images and are displayed using rear projection techniques. Digital information can also be recorded on the disk. 150KB of digital data can be included on a disk that also carries 6,000 page images. The amount of digital data can be increased, but it will encroach upon image storage capacity. The machine-readable data can be used to access the required page images. Graphics are stored in the outer rings of the disk, and digital data on the innermost rings.

The disk handles like a floppy disk. It is read using a special workstation with a rear projection viewer which projects full-sized images onto a display screen. Image quality is said to be equivalent to that achieved with scanned images digitized at 200 lines per inch and displayed on high resolution (2,000 line) monitors. The workstation also includes a microcomputer and a full detached keyboard. The workstation can be configured with an RS-232 communications interface to provide printout capabilities and connection to a local or remote computer so that updatable information may be accessed. Workstations cost around $3000. An image can be located on a disk and displayed in one second. A carousel option is under development to handle disk selection and loading when multiple disks are used.

Recording facilities are expensive, and are not likely to be available at user sites. A glass master can be created for $2,000. Copy prices vary with quantity.

Mnemos, of Lawrenceville, NJ, is thought to have at least four beta test sites for its system.

CHAPTER 10. ERASABLE OPTICAL MEDIA

When optical-based mass storage media began to be developed, the fact that these were write-once devices without erasability was regarded as a major shortcoming by some observers. Information can be added to unrecorded areas of the disk and obsolete information can be made inaccessible, but it is not possible to erase data and update it in place. Others welcomed the lack of erasability pointing out that the optical storage media will occupy a different place in computer storage hierarchy than most magnetic media and that non-erasability has advantages for applications such as archival storage and massive data collection jobs where there is more need to preserve the information than to erase and update it.

Adding support to this view are the cost considerations. Because optical media typically contain up to 100 times the storage capacity of the same size magnetic media, they provide storage at a small fraction of the cost per byte for magnetic media. Being able to erase and re-use an optical disk is not as much of an economic consideration as it is with more expensive magnetic disks.

There are applications, however, in which it seems likely that a low-cost erasable optical media which combines the random access capabilities of magnetic disk and the removability of magnetic tape would have great market appeal. A number of companies are researching the development of such a medium and prototype erasable optical disks have been demonstrated. At present, no such media is commercially available.

One approach to erasability uses photochromic materials which change color or darken when exposed to light of certain wavelengths or power densities. They revert spontaneously when the stimulating light is removed (the principle on which eyeglasses which darken outdoors and lighten indoors work) or

when stimulated in a certain way such as by the application of ultraviolet light.

Corning has undertaken research into a film containing both silver chloride and metallic silver deposited on a transparent substrate. Before exposure to light the film transmits light equally without regard to polarization; exposure to polarized visible light impresses polarization sensitivity onto the material. The media is read using an infrared beam with a polarization rotated 45 degrees from that of the write beam. Erasure is by irradiating the material using a light beam with a polarization different than that of the original recording beam.

Most photochromics suffer from some combination of being too insensitive, too impermanent in storing data, too expensive or too hard to read.

A second approach uses phase change optical media. In certain metal-like materials an amorphous to crystalline phase change may be effected by the application of heat. For those materials which show significant differences in optical properties between the two states, the pattern of state alterations can easily be read by optical means. In prototype systems, a laser beam is used to change the temperature of the material and cause a local change from amorphous to crystalline structure, or vice versa in some cases. Most phase change research uses substances in which the crystalline form is more reflective and opaque than the amorphous material, and which require less energy to initiate the amorphous to crystalline transition than to go the other way. Hence erase power need only be half the write power.

Until the substance becomes fatigued, these media can be erased and rewritten numerous times. Various developers are reporting fatigue times ranging from a few hundred read-write

cycles to over one million. The former level is sufficient for most applications, particularly in small systems.

The chief benefits of phase-change-based erasable media are relatively high signal-to-noise ratios and good signal properties which support high density recording. The major disadvantage appears to be that the process is highly temperature dependent and requires very precise control of the reading and writing characteristics of the drive system. Fatigue and degradation are also of concern.

A third method of supporting erasability employs magneto-optic materials. Magneto-optical recording relies on a physical connection between the magnetic and optical properties of certain rare earth materials in which it is possible to detect an optical change--a change in reaction to reflected or transmitted light--after a magnetic change has occurred. Such materials are laid down in a thin film and written by heating with a small light spot while immersed in a moderate magnetic field. When the heat is removed, the magnetization remains. Data is erased by reversing the direction of the applied magnetic field then repeating the recording process. It is thought that these materials will exhibit the same sensitivity as write-once media, that their practical storage densities will be about 30 percent lower, and that commercial disk prices will be about 50 percent higher.

Disadvantages of the magneto-optic approach include poor signal-to-noise ratios which require relatively large pits to be made to record data--limiting the storage capacity--and relatively low recording and playback rates.

3M has released a product brochure describing an erasable magneto-optic disk. The 5-1/4 inch disk has a projected capacity of between 300 and 500 MB.

Matsushita, Panasonic's parent company, demonstrated an erasable optical disk in 1983. The 8-inch disks utilize the phase change approach acting on a tellurium suboxide, the reflectivity of which changes when a laser beam is applied. The material is said to have a much higher sensitivity than other tellurium derivatives making erasability feasible. The company claims that the medium will support over one million record, playback and erase cycles. Disk capacity and bit error rate are reportedly poorer than for nonreusable disks. The disk is not expected to be in mass production for several years. It is based on technology developed and licensed by Energy Conservation Devices, Inc. of Troy, MI.

CHAPTER 11. LIBRARY AND INFORMATION APPLICATIONS OF VIDEODISC AND CD ROM

The literature of library and information technology has been replete with references to the promise of videodisc technology since the middle of the 1970s. However, the only information-oriented videodisc product that has been made widely available for information applications--Pergamon's Video Patsearch--was abandoned. Early in 1985 several prototype commercial applications of the videodisc and CD ROM as digital data publication media began to emerge. None were in sufficiently widespread use to permit in-depth assessment of their performance.

Apart from having generated innumerable papers and conference sessions, the major impact of the media on libraries and information centers to date has been in straight audiovisual applications. A number of libraries have incorporated videodiscs into existing audiovisual collections of films and videocassettes. As compact audio discs become more widely available this format will be added to existing sound recording collections and, if the CD ROM application of the disc develops as observers have predicted, it is assumed that libraries which maintain collections of computer software on floppy disk will also acquire software and data bases published in this format.

This chapter examines a number of video and compact audio disc projects currently being developed or investigated in library and information related applications. Projects which use the media for audio and/or video storage--Video Patsearch, the Library of Congress' non-print project, and work undertaken by the National Library of Canada and the National Library of Medicine--are examined first; the emerging applications which utilize the media for digital data publication follow. Organizations which have demonstrated an active

interest in the latter field by the preparation of prototype commercial systems include Library Systems and Services Inc., Carrollton Press, The Library Corporation, Information Access Corporation and a number of data base and software vendors.

Organizations developing plans or products based on the optical digital disk technology are discussed in chapter 12.

AUDIO AND VIDEO APPLICATIONS

Video Patsearch

The first commercial application of videodisc technology in information storage and retrieval, Video Patsearch, was introduced by Pergamon in 1981. Videodisc provided the publication and distribution medium for the drawings and chemical patents issued since 1971.

The discs, distributed to end-user sites, were designed to support searches of Pergamon's online Patsearch data base with the full text of patents. Using a specially configured workstation, a user would dial up the remote online search system and conduct a search of the data base. The results of the search were transmitted to the microcomputer terminal which automatically retrieved the related image data from the disc for display on a videodisc monitor. The workstation included a microcomputer with a keyboard and an integrated telecommunications interface; two viewing screens--one for computer generated text, the other for graphics from the videodisc; a laser videodisc player; and a printer. The images could be output in hardcopy on the printer.

Technically, there were apparently no problems with this application of videodisc technology. Eight different videodiscs were produced and users appeared to be satisfied with the quality of the images provided by the system. However, the application was not a commercial success and the company recently admitted to having dropped the videodisc product. It continues to support the online Patsearch data base.

Company spokespersons attribute the failure of the Video Patsearch product not to the technology, but to an overestimation of the potential market. Because of the pioneering nature of the application and a desire to maintain product development security, it is reported that little market research was undertaken. There is also some feeling within the company that full market penetration would have required an industry-wide change in traditional patent retrieval practices; changes that went far beyond adapting to the use of a new technology to encompass a restructuring of the patent retrieval industry, with the work being undertaken in the offices of patent attorneys rather than being contracted out to specialized search services.

National Library of Canada

In 1982, the National Library of Canada produced a CAV formatted videodisc as a demonstration project to illustrate:

- o the ability of the videodisc to store and present library materials in a variety of formats,
- o the use of videodisc as a practical research tool for Canadian studies, and
- o the information retrieval capability of a combined videodisc-microcomputer system.

The disc contains four program sequences. Side one presents two republished public relations presentations: a sound and motion sequence--Canada's National Library--originally produced as a 16mm film, and Canadiana, a 35mm slide show. Side two contains two productions specifically created for the disc: The History of "O Canada", designed to illustrate the use of videodisc in research, and A Walk Through the National Library, a public relations tool aimed primarily at librarians showing services offered to users.

The History of "O Canada" contains photographs, in both black and white and color, music scores, manuscripts, newspaper clippings, and official publications; excerpts photo-

graphed from books, newspapers and microfilm; items written in pencil, mimeographed, and photocopied; items on different types of paper; and postage stamps. Sixteen versions of "O Canada" are heard on a variety of sound recordings, some of them dating back to the late nineteenth century.

Overall, the physical characteristics of the materials produced on the disc have been judged to be satisfactory, at least for demonstration purposes. However, there have been problems with the software and index which are mounted on an Apple II Plus microcomputer. Copyright considerations have been a major impediment to the widespread distribution of the disc.

It is expected that this and other applications of technologies will be fully explored in a National Library of Canada report Library Applications of Videodisc and Optical Disk Technology due to be published at the end of 1984. A less specialized report on potential applications of optical disk technology in Canadian federal government departments is expected to be released in 1985.

National Library of Medicine

The Lister Hill Center for Biomedical Communications at the National Library of Medicine has an impressive record of involvement with videodisc technology. In addition to producing an experimental interactive videodisc program to direct users of the National Library of Medicine and several instructional videodiscs, the Center also undertook early research into the publication of digital data on videodisc and has explored the integration of videodisc technology into sophisticated information retrieval and learning systems.

The Center's experience in the production of the interactive CAV videodisc for visitor information is extensively documented in Videodisc Premastering Facility: Technical

Evaluation, Lister Hill Technical Report LHNCBC 83-10. The report is available through the National Technical Information Service as document number PB84-135821. Among the user considerations addressed in the project were: preferences for menu- or keyword-driven access to the information stored on the disc (a menu-driven approach was chosen on the assumption that most visitors would have little foreknowledge of the institution and its services), the need to provide video displays that would allow the system to be used without the aid of manuals or workbooks, and modification of standard equipment components to enhance ease of use.

In its report, the Center estimates that premastering of the material for the disc required 1,585 person hours. In addition to graphics and video input development, the programming to control the Level two disc was also undertaken in-house. Mastering costs for two proof discs and 20 copies of the disc totalled $6,260.

Instructional videodisc programs being developed and tested by Lister Hill include interactive discs on medical pathology, radiology, and dental technology. The work on the radiology program includes assessment of the success with which radiographs can be reformatted to video images with clinically significant qualities.

Library of Congress

The Library of Congress is undertaking an extensive pilot project to explore the potential of optical storage media in library preservation, storage and service applications. The project is in two parts, with nonprint images being stored on videodisc. Compact audio disc recording of sound materials is also being investigated. The other part of the project--the storage of digitized images of print materials on optical digital disk--is described in the next chapter. The literature the Library has distributed in association with its pilot

projects represents some of the most focused discussion of the potential of these media in library applications. It is used extensively in the following description of the non-print project.

The non-print part of the Optical Disk Pilot Program is an experiment. If the discs help the Library perform its work better, more use of them will be made in the future; if not, little further use of them will be made. Since the discs will probably be of greater use for some materials and purposes than others, the experiment will identify the areas of greatest utility.

Two types of discs are being created as part of the non-print experiment: videodiscs for visual materials, and compact audio discs for sound recordings. A total of eight discs--six videodiscs and two compact audio discs--will be created, containing the following materials from the Library's collections:

- Prints and Photographs Division. About 40,000 images from eight collections. The collections include the World Transportation Commission collection of lantern slides; the Detroit Publishing Co. glass negatives, color prints, and albums; the Farm Security Administration and Office of War Information color transparencies; the Abdul-Hamid II Collection; the Yankee Poster Collection; and a group of selected architectural drawings.
- Prints and Photographs Division. About 10,000 images from the Cabinet of American Illustration, the American Cartoon Drawings Collection, and the Master Architectural Drawing Collection.
- Motion Picture, Broadcasting and Recorded Sound Division. Nearly 100,000 motion picture publicity stills.
- Motion Picture, Broadcasting and Recorded Sound Division. A selection of seven films and film segments

with special color preservation problems. Titles to be included are Women of Tomorrow, Unusual Occupations, With the Marines at Tarawea, Alaskan Grandeur, Jewel of the Baltic, A Hatful of Dreams, and picture-only test segments from Taxi Driver.

- Motion Picture, Broadcasting and Recorded Sound Division. A selection of 30 titles from the 3,000-item paper print collection. These films focus on President William McKinley, his assassination, and the 1901 Pan-American Exposition.
- Motion Picture, Broadcasting and Recorded Sound Division. Two CBS Television network newscasts from the 1976 fourth of July weekend.
- Motion Picture, Broadcasting and Recorded Sound Division. Two concerts recorded in the Library's Coolidge Auditorium.

Preservation is a major focus of the project. If the media live up to their promise, the videodisc and compact audio disc technologies could be applied in four ways. First, discs could reproduce items with sufficient quality to permit the Library to consider discarding the original. Second, the use of discs could substantially decrease the wear and tear on collections caused by handling. Third, some discs may offer a kind of preservation compromise: although they will not reproduce the item perfectly, they could offer the Library the best possible preservation option at this time. And fourth, there are a few collections that will be enhanced by the very act of putting them on disc.

The two audio discs and the teleproductions videodisc should perfectly reproduce the items they represent. The NTSC television signal, however, cannot faithfully reproduce the fine detail of an architectural drawing or a large-format photograph. The disc with drawings and photographs is expected to serve a preservation function by reducing the need

to handle the original materials. The still images are being photographed on 35mm motion picture negative film, which is transferred to video for disc mastering. The choice of 35mm film provides a higher resolution than the NTSC signal requires (16mm would probably suffice). Film itself is also a preservation medium. It will be properly stored, and, in the future, if a high-definition television standard comes into use, can be retransferred to video without the need to rephotograph the collections.

Videodiscs may be able to retain image color more accurately than some motion picture film stocks. Not only do some film prints suffer from color shifts, but their negatives may also change color in time. Thus, even though the NTSC television signal is incapable of reproducing every nuance of a motion picture image, the Library's creation and assessment of a videodisc for motion picture color preservation could show it to be the only feasible preservation medium for certain films.

The second motion picture videodisc represents another aspect of preservation, perhaps better called restoration. The paper print collection dates from the very earliest days of film and film copyright. The Library's original copies of this historically important body of work are literally on paper rather than on film. The imagery is unstable in various ways, and the speed (frame rate) fluctuates. The transfer to videodisc will involve sophisticated analysis of the footage, and frame-by-frame image correction.

The non-print experiment is also seen as making an indirect contribution to the goal of an integrated catalog: using a single approach--the Library's computerized catalog--to inform a researcher of all relevant holdings in the institution. The program's indirect contribution to this goal will be derived from the discs containing the Prints and Photo-

graphs Division collections, but the work may serve as a model for other special collections.

The non-print experiments address five facets of the read-only videodisc and compact audio disc technologies:

- o Technical. The creation of the discs presents the Library with a set of production and design problems. What is the best and most efficient way to prepare materials to be put onto a disc? What captions and menus are required, and how shall they be created? Which production steps can best be performed in-house, and which by an outside contractor?
- o Copyright and gift restrictions. The Copyright Office has determined that materials with valid copyrights may not be displayed to the public without the permission of the copyright holders. Similar restrictions may be in force as part of an instrument of gift. The project will confront these issues when they arise. If a large number of discs is to be created in the future, a procedure to obtain permissions will have to be developed.
- o Preservation. The preservation facet of the non-print experiment will test the endurance of the discs, not the collections they contain.
- o Research access and use. This facet of the experiment will determine how well the discs perform for the Library's readers. Can users of the still image discs find the pictures they seek, and identify them? Will motion picture researchers be satisfied with the disc's representation of a feature film? How well does the playback equipment work? Is it easy to operate?
- o Dissemination. Information about the program will be disseminated by presentations and demonstrations and by preparing publications and news releases. In addition, other libraries and research institutions will

be permitted to borrow selected discs and their accompanying booklets and data.

It is expected that the three still image videodiscs (prints and photographs, and motion picture stills) will permit a valid and thorough test of the use of videodiscs in supporting access and retrieval to large image files. In this area, the disc is not regarded as a direct preservation medium but rather a service tool which accomplishes preservation objectives indirectly through reduced handling of the original materials. The access and use experiment for the three still image discs will test two different retrieval methods. For the Prints and Photographs Division materials, a small computer will provide captions and a retrieval system. For the film publicity stills from the Motion Picture, Broadcasting and Recorded Sound Division, a simple, alphabetical title index will be used.

Because compact audio discs are a full preservation medium, the main thrust of this part of the experiment will be preservation testing. If these discs live up to their promise, library sound collections--especially those most endangered by physical deterioration--could be transferred to digital form and to digital discs as resources permit.

The non-print project provides other opportunities for exploring various aspects of the technologies. These include workstation design and evaluation, the use of text overlays on video images, and analysis of user reactions to the various systems.

Overall, the Library of Congress' non-print project promises to offer libraries, museums, and film and photography archives a wealth of evaluation data to guide future applications of videodisc and compact audio disc in these areas.

Other Library-Related Products

The videodisc-computer interfacing products described in chapter 3 provide libraries, information centers, and commercial vendors with the opportunity to develop customized applications based on videodiscs produced for the general market. Videodiscs of visual images from the collections of museums, galleries, and libraries--image data banks--appear particularly well suited to such applications. An increasing number of such discs is becoming available from institutions such as the National Gallery of Art, the National Air and Space Museum, and--possibly--the Library of Congress.

At least one automated library system vendor--AdLib--has demonstrated the ability to link videodisc players to its automated library system. Promotional material emphasizes image data bank applications using commercially published videodiscs. The AdLib data base management system and other system software can be used to create an online index of the images on the discs. No emphasis has been given to the use of the linkage to provide access to machine-readable data bases of bibliographic records stored on videodisc.

DIGITAL DATA PUBLISHING

MiniMARC

For a number of years, Library Systems and Services Inc. of Rockville, MD has provided standalone machine-readable support for cataloging through its MiniMARC system which uses LC MARC records stored on floppy disks as the source of bibliographic information. The system functions as a tool for the creation of adapted local records and for doing original cataloging. It is also used for the retrospective conversion of manual records to machine-readable form.

The floppy disk-based system has been well received but is cumbersome to use. Identification and retrieval of records requires a four-step process of microform index lookup, manual

recording of the number of the floppy disk on which the required record is stored, selection and mounting of the appropriate disk, and keying of the record number. Late in 1984 LSSI was in the process of replacing the microform/floppy access/storage part of the system with a videodisc data bank produced using LaserData technology.

The floppy disk-based MiniMARC system consists of a central processing unit, a three-drive floppy diskette unit, a CRT display and a keyboard. The three disk drives contain the software, the data base (read only to prevent erasure) and a blank diskette to store the amended records.

Over 1,300 floppy diskettes in a separate bookcase cabinet constitute the resource data base. The appropriate diskette is identified by searching an index on a cartridge microfilm reader by LC card number, author, or title (author and title are interfiled) and obtaining the diskette number and LC card number (if not already known). The author and title entries reference the LC card number and all entries give the diskette number. Both the LC card number and diskette number have to be noted before the appropriate diskette is selected and the required record retrieved. Retrieval is accomplished by inserting the appropriate diskette into one of the drives and using the keyboard to retrieve the record by LC card number.

An optional printer is available for printing cards. An optional tape drive is also available or the diskettes containing the local records may be sent to the vendor for reformatting to magnetic tape. An interface supports the online transfer of records into any one of several turnkey automated library systems.

MiniMARC has been marketed primarily to medium-size public libraries--those cataloging at least 8,000 titles per

year--although there are some customers which have a lower cataloging volume. Recently there has been more emphasis on the utilization of MiniMARC as a retrospective conversion tool.

The product appears to be highly regarded by the libraries using it. Throughput on the system is good, with nearly 17,000 titles per year handled on a single system used only during regular daytime hours at one user site and 24,000 titles per year on a system used on a two-shift basis at another location. These figures are well above the 36-40 records per hour claimed by LSSI. Library staff using the system report that MiniMARC is easy to learn and use. However, users have expressed concern about the time it takes to look up LC numbers in the microfilm index.

The basic price for the MiniMARC system is between $45,000 and $55,000 for the first unit and $35,000 for each additional unit. The updates are $4,620 per year. The microfilm index is updated every week to reflect the new records distributed weekly on diskette. Maintenance on the basic system is $440 per month. The system may be leased for $1,700 per month plus maintenance of $440 per month and a data base subscription of $385 per month.

Approximately 50 systems have been installed under sales, leasing and lease-purchase agreements. Short-term rentals for retrospective conversion projects are also available. Although medium-sized public libraries were originally among the heaviest users, later purchasers included increasing numbers of processing centers and library systems doing centralized processing. Such users now account for approximately 20 percent of MiniMARC customers, with academic, special and school libraries comprising another 40 percent of the client base.

The videodisc enhancement replaces the microform index and the floppy disks on which the MARC data base is stored. The change of access and storage media requires the addition of a videodisc drive and controller to the hardware package. The videodisc contains both the MARC data base and the Mini-MARC indices. The data base and indices will be updated by issuing a revised videodisc twice a month.

The initial cost for new customers is expected to be no higher than for the present system, and present customers will be able to upgrade for only the cost of adding the videodisc drive and controller--approximately $4,500. It is expected that with the enhanced system current productivity estimates of 35 to 40 records per hour, exclusive of bibliographic editing time, can be significantly improved. The BiblioFile system can also support multiple users.

The combination of an established customer base and an application which promises time and labor saving at no price increase over that of the existing system places LSSI in an excellent position to test the effectiveness of the videodisc as a machine-readable data publication and distribution medium.

Information Access Corporation

In 1983, Information Access Corporation (IAC) demonstrated aspects of a research and development project for reference services based on the publication of machine-readable data on videodisc. The Optically Stored Computer Assisted Reference (OSCAR) system would combine the use of microcomputers, videodiscs, and satellite communications. Videodiscs produced using technology such as that offered by LaserData would be used to distribute the machine-readable text of magazine articles. The data would be accessed using a microcomputer and a commercial videodisc player. New discs would be published and distributed regularly. Between issues

of disc updates, the store of machine-readable text might be updated using satellite data transmission. A small satellite receiver developed by Equatorial Communications was suggested as the data receiving device to be installed at user sites. It was also suggested that the incoming data could be stored on Winchester disks, and erased when made obsolete by the arrival of the next issue of the videodisc. When it demonstrated its initial interest in videodisc publishing, IAC intended to begin marketing a system based on the OSCAR concept in 1985.

Early in January 1985, IAC demonstrated a prototype of its videodisc-based InfoTrac system which will be available for purchase in March. InfoTrac combines videodisc storage and microcomputer technology to provide access to an index of the contents of over 1,000 business, technical, legal, and general interest publications.

The index is arranged by Library of Congress Subject Headings and covers the period 1982 to date. The subject headings, personal and corporate name headings, and authors and titles are arranged in a single alphabetic sequence. Cross references are included.

The machine-readable index is stored on one side of a 12 inch videodisc. LaserData technology is used in premastering the disc. The index will be updated monthly. This will be achieved by issuing a new, cumulative videodisc each month.

The system can support four simultaneous users. The hardware configuration consists of up to four IBM PC microcomputers (one for each user station) each with 225 KB of memory, one videodisc player, one videodisc interface unit, and a printer. All system components are secured to protect against theft. Individual workstations may be located up to 100 feet from the disc player. The retrieval software is distributed on floppy disk.

The software is designed for ease of use. The searcher responds to menu prompts to define the information required and the user may choose to view either a display of headings, subheadings and cross references, or the full index with headings and citations. Citations give full bibliographic details and are self-explanatory--no abbreviations are used. An accession code is included in the citation if the full text of the indexed article is available on one of IAC's companion products--the microfilm Magazine Collection and Business Collection.

Movement to and from the index term only and the citation listing is accomplished by a single keystroke. The system allows the user to browse, and printing may also be accomplished with a single keystroke. The system supports neither keyword or Boolean searching.

IAC promotional literature indicates that "references can be retrieved in less than 10 seconds." Although no attempt was made to confirm this, the authors' experience in using the prototype system suggests that response time is adequate, even with multiple users.

As currently implemented, InfoTrac does not include the text of the document indexed. Nor has IAC yet configured a companion microform publication which matches the coverage of the index. Libraries wishing to use IAC products to provide access to the indexed documents would need to subscribe to both the Business Collection and the Magazine Collection. Future developments will depend upon users' reactions.

A full InfoTrac system--the hardware for four user stations and a videodisc updated monthly--is priced at $16,000 per annum. This price also includes annual hardware maintenance. Subscribers have the option of configuring systems with fewer than four user terminals, and of including addi-

tional printers. After five years of annual payments, the purchaser owns the hardware and need only to pay the $8,500 subscription for the monthly data base distribution and an annual charge of $2,500 for hardware maintenance. Institutions which have access to the IBM PCs used as workstations may opt to purchase the printer, player, controller, and interface cards and cables only for a one-time charge of $7,000. Such organizations would be provided with the data base for the annual subscription of $8,500, and hardware maintenance for a further $2,500 per annum.

Carrollton Press

Carrollton Press, the vendor of the REMARC bibliographic data base, demonstrated a prototype videodisc-based reference support system at the June, 1984 meeting of the American Library Association. MARVLS--the MARC and REMARC Videodisc Library System--offers subject access to a file of machine-readable MARC and REMARC records stored on videodisc. As demonstrated, the system included an IBM PC and a videodisc player. The system was again demonstrated at the January 1985 meeting of the Association. This version of the system used videodiscs premastered by RTI, an approach which requires the use of RTI's customized videodisc player. The six million MARC formatted records and accompanying indexes are expected to occupy two single-sided videodiscs. The data is accessed using proprietary search software which includes Boolean capabilities. The system is capable of being configured to support up to twelve user stations.

Carrollton also showed two new prototype systems--DisCon and DisCat--at the January meeting. Both are designed for cataloging support and utilize CD ROM as the storage medium.

DisCon is aimed at the retrospective conversion market. Some 6 million MARC and REMARC records are stored on eight 4-3/4 inch CD ROM discs. The records are stored in LC Classi-

fication Number order, a design feature chosen to maximize system performance for conversions based on shelf list files. In addition to being accessible by LC classification number, records can also be retrieved by other keys such as author-title, title and Library of Congress card number. Qualifiers such as place, date, pagination and language can also be applied to narrow the search.

DisCat is a current cataloging tool which provides access to recent MARC records. The production of card and spine labels would also be supported.

The applications software for all products is currently published on floppy disk. As of early 1985 Carrollton had not finalized its plans for marketing the various systems. Hardware configurations were still to be determined as was pricing. Publicity material suggests that MARVLS might be made available to libraries under a lease arrangement and DisCon on a lease arrangement plus a separate per record charge. Possible pricing approaches for DisCat are not clear.

The Library Corporation

Whereas Library Systems and Services Inc. (the vendor of MiniMARC) and The Library Corporation (the publisher of the ANYBOOK microfiche which provide author, title, keyword, subject and publisher access to records of books published in English over the last ten years and other English language books in print) initially undertook joint development of a videodisc-based product, the two companies had evolved different approaches by the time of the American Library Association meeting in January 1985. The Library Corporation has developed a cataloging support system--BiblioFile--which utilizes MARC records stored on CD ROM; LSSI has chosen to utilize videodisc as the storage medium for its MARC data base.

In the BiblioFile system, LC MARC records for English language materials are stored on two 4-3/4 inch CD ROM discs. In addition to the LC MARC English language data base, the discs also contain the ANYBOOK acquisitions data base of some two million in-print and recently out-of-print English language books. Price, binding, discount, and availability data are included. A publisher data base of over 19,000 names, addresses, phone numbers, and SANs is also included. This file has been designed to be accessed by publisher number and ISBN prefix. The MARC records for the period through 1974 are stored on one disc, records from 1975 are on the second disc.

The Library Corporation markets BiblioFile as a catalog production system for the IBM PC with one floppy disk drive and 256 KB of memory or the OCLC M300 workstation. It is promoted for both retrospective conversion and current cataloging. In addition to a laser disc drive, the company provides BiblioFile access software and catalog production system software. The software enables a library to retrieve a MARC record by title, author, Library of Congress card number or ISBN and ISSN. The search may be qualified by date and other parameters such as place and pagination. The retrieved record may be edited online and the resulting record stored on floppy disk for later conversion to tape. The software also allows the printing of catalog cards and spine labels. The system also supports original cataloging and provides for the preparation of orders for MARC or REMARC records from other, external sources. The additional files are also stored on the second disc. The Library Corporation has not yet developed applications software to utilize the ANYBOOK and publisher data bases.

The Catalog Production System is available for a one-time purchase price of $2,930. This covers a Hitachi compact laser disc drive, the BiblioFile access software and the Catalog

Production System software. An annual subscription to the LC MARC English language records on compact laser discs, recompiled and replaced quarterly, is $870. No per record usage charges are levied. It is expected that by July 1985 the data base will be updated weekly rather than quarterly. The annual subscription price will then increase to $1,000. The initial discs were produced by Hitachi (Denon) in Japan. The Library Corporation intends to have the discs produced in the U.S. once production facilities become available.

Earlier publicity material from The Library Corporation illustrated another potential use for a disc-based product utilizing the ANYBOOK data base. The application is linked to the American Booksellers' Association's Book Ordering System (BOS). BOS is being developed to provide bookstores with an inexpensive way of speedily relaying orders to publishers. The bookseller uses a personal microcomputer to prepare orders offline. These orders may be printed and mailed or electronically transmitted to the BOS mainframe in New York from whence they are distributed to the designated publisher or wholesaler.

While the BOS mainframe houses a file of data on the items published by participating publishers and the system requires that publishers update this information monthly, the data is used only for mainframe processing and transmission of the orders. As presently conceived, BOS does not provide participating bookstores with access to an online data base that can be queried to determine which publishers provide which titles. However, there are a number of ways in which the system hardware can be used to provide this information. A machine-readable version of Books in Print is available on Dialog and the hardware can be used to access this file. As an alternative, a number of publishers are developing machine-readable versions of their publication lists for distribution for local use on the BOS system. Houghton-Mifflin is making a floppy disk of its titles available to stores using BOS.

It is possible that future development of the BOS system might provide direct online access to publishers' list data. Distribution of The Library Corporation's file on videodisc is another option.

Other Companies

At the June 1984 ALA meeting, CLSI, a major vendor of turnkey automated library systems, demonstrated a videodisc-based cataloging support system known as Lasercat. Developed by a British company, INCubator, the system provides local cataloging capabilities on an IBM PC using a resource file of machine-readable MARC records stored on a videodisc. The disc is accessed using a standard videodisc player and appropriate interfacing software. CLSI is believed to have delayed marketing of the system because of concerns that the technology is not yet cost effective.

With its mid-1984 announcement of the establishment of a new subsidiary--Wilson Cambridge Inc., headed by Robert Nelson and Martin Hensel, both of whom were principals at LaserData--the H. W. Wilson Company appears to be well-positioned to enter the videodisc-based data base publishing arena. No product announcements have yet been made and an immediate offering seems unlikely given that the company has only just launched its online data base service, Wilsonline.

Companies which market data base formatting and search software have also expressed keen interest in videodiscs and compact audio discs as digital data publication media. BRS was one of the early financial backers of LaserData, and recently announced an agreement to exchange technology with and market, Reference Technology Inc.'s CLASIX system for premastering digital data for publication on videodisc. RTI will market the BRS/SEARCH software. The agreements are non-exclusive.

BRS sees read only digital publication as an opportunity to achieve more sales and use of its software. There are two places in the digital publishing chain where BRS could offer services. A raw machine-readable data base has to be formatted before it can be searched. For machine-readable data that is to be published on videodisc, this takes place before the file is transferred to videotape preparatory to disc mastering. Through its online activities, BRS has developed the software for formatting such files and creating the associated dictionary and inverted file indices. BRS can format both full text and bibliographic files, processing the raw data at a rate of 50MB in four hours. Such processing normally results in an output file one-and-a-half times the size of the input file, although smaller increases—with an overhead of 33 percent rather than 50 percent--have been achieved on some full text files.

The second area of interest concerns the BRS Search retrieval software. Sales could be increased if data base providers designing their files in such a way as to require the use of BRS Search for most effective access and utilization. This would result in increased sales of the software to users wishing to access the discs on whi such files are "published". Another option is to package the Search software on the disc, encoding the retrieval program along with the data. Demonstration discs produced by LaserData use BRS search software. Some industry observers expect BRS to make a product announcement "at any moment."

Battelle has also publicized its interest in the field, although the major focus of its attention now appears to be CD ROM rather than videodisc. Battelle is interested in the "packaging opportunities" offered by CD ROM and the possibility of publishing the search software along with the data files on CD ROM. Battelle is involved in negotiations with

"one of the big computer vendors" which is about to move into the provision of CD ROM memories and drives.

A Battelle spokesperson has addressed the characteristics essential to a successful CD ROM publication program. An application should encompass a large amount of data in the form of a single file or a large number of small files; information which is not volatile--which may require the addition of more information, but little change to existing records; information for which there are many potential users to allow economies of scale to be realized in disc replication; and a product which is marketable for a fixed price.

CHAPTER 12. LIBRARY AND INFORMATION APPLICATIONS OF THE OPTICAL DIGITAL DISK TECHNOLOGY

The situation in relation to applications of the optical digital disk technologies for library and information systems is the same as that for the storage of digital data on videodisc--there are not yet any fully operational systems. While the success or failure of optical storage systems will be determined by market forces broader than the specialized field examined in this report, studies of the performance and use of optical storage media in library and information applications can be expected to yield useful data on a wide range of factors, not just those relating to optical storage media.

LIBRARY OF CONGRESS

The experimental projects currently being undertaken by the Library of Congress appear to be those most likely to provide the data for a realistic assessment of the potential of optical digital disks in library and information applications. Documentation that the Library has issued in association with its activities in this area also constitutes some of the most focused discussion of the potential of the media for libraries and information systems.

The Demand System of the Cataloging Distribution Service

In 1982, the Library of Congress announced that the Cataloging Distribution Service (CDS) was using optical disk technology to store library catalog card images.

The technology that was being implemented by Xerox Electro-Optical Systems of Pasadena, CA for installation of the DEMAND System comprised a computer driven optical disk mass storage system, retrieval capabilities and a laser printing system for the demand printing of non-MARC catalog cards. The system was dedicated in August 1982 and is intended to gradually replace the manual system by which CDS produces non-MARC printed cards.

In August 1982, CDS began scanning images from nonMARC LC master cards into the DEMAND system. (Details of the scanning process are given in the Appendix.) System design is based on optical disk storage of highly compressed images using laser input scanning, keyboarding of the Library of Congress card number for control and retrieval of image data, and laser xerographic printing for the output processing and distribution of two sheets of six card images each per second. High resolution cathode ray tube (CRT) displays (1,024 lines) are used for editorial and image tagging during the input process.

Scanning and printing are effectively 480 lines per inch. Such high scan densities are used to capture fine detail such as the delicate horizontal strokes in Chinese ideographic characters. Image enhancement is a feature of the input system, allowing an operator to adjust the scanning laser's sensitivity to gray scale levels in order to prevent the recording of stains and other marks on the original image.

In its early announcements, the Library indicated that "since images are being stored as opposed to coded data, it is somewhat difficult to say how many card images can be stored on the optical disk which Xerox Electro-Optical Systems (XEOS) is manufacturing and creating. Images are compressed and stored on disk at a reduction of approximately 20 to 1. White space is stored in coded form, not proportionately, thus permitting greater image compression. One estimate projects storing over 200,000 images in digital form on one side of an optical disk. 4.7 times 10^{10} bits can be stored on one side of one 14-inch XEOS disk. 5.5 million images may be stored for retrieval on approximately two dozen digital disks. The first full optical disk was scheduled to be prepared in early 1983 following the successful input and tagging of 200,000 images. Images are stored initially on magnetic disk packs (11,000 per pack) to afford correction and interim use in filling orders". Source: "The DEMAND System of the Cataloging Distribution Service," Rev. Nov. 5, 1982, Cataloging Distribution Service, Library of Congress.

There is no doubt that the digitized scanning of card images has fulfilled its promise. The Library has shown numerous examples of original cards and copies made from the stored digitized images of these cards which are impressive with regard to the quality of image enhancement achieved.

However, progress on the implementation of the optical disk storage aspect of the DEMAND system is disappointing. As of late 1984, the Library had not implemented this aspect of the system design. The custom developed optical media originally proposed was replaced by commercial products--the Optimem drive and Optimem disks. Test data had been mounted on this equipment, but problems were being encountered. It was not clear whether the difficulties, which included an inability to retrieve some items known to be recorded on the disk, were related to the disk technology or to the software developed for the application.

The Optimem disks have a lower capacity--1GB per disk side--than the original 5GB disks. The change to lower capacity disks will require the use of at least 100 optical digital disks to hold the DEMAND data, a sharp increase over the two dozen (later 30) projected at the beginning of the DEMAND project.

Optical Disk Pilot Program

In April 1982, the Library of Congress issued requests for proposals for an Optical Disk Pilot Program comprising two parts: the storage of non-print or image-based materials on analog optical discs (optical videodiscs and compact audio discs) and the storage of digitized images of print materials on optical digital disks. The non-print part of the project is described in the previous chapter. This account focuses on the optical digital disk project--the print project.

The print project uses scanning and storages approaches similar to those being tested in the DEMAND system: documents are scanned and the digitized image passes through compaction routines before being stored on disk. The print project system, being developed by Integrated Automation, includes five major elements:

- o An input system of a page scanner capable of scanning pages up to 11 x 14 inches at a resolution of 300 lines per inch. The scanner can be fed manually or automatically. The system also includes a microfiche scanner which requires the manual positioning of the fiche.
- o An optical disk storage system. Magnetic disk buffers will be used to allow quality review of the scanned input before the image is written to the optical disk, and to provide temporary storage of material retrieved for use. A Thomson-CSF optical disk read/write unit --a machine which makes and plays the disk--and a jukebox which stores 100 disks and can select and play them one at a time complete the system. The system utilizes Thomson-CSF disks.
- o A processing system. All functions of input, output, and communications are switched through this computer system.
- o An output system. A terminal cluster controller, frame buffers, video system and printer interfaces, and up to eight 2000 lines high-resolution viewing terminals--some with attached convenience printers--are used for output. The system will have six public-use terminals and two modified slow-speed Xerox 2700 printers with a print resolution of 300 lines per inch.
- o A high speed printer. A modified Xerox 5700 with a print resolution of 300 lines per inch will be used for offline batch printing.

When the system is operational, documents will be scanned onto magnetic disk and stored for quality review. As pages and documents are approved, they will be written onto an optical disk. Indexing information for retrieval purposes will also be written onto the disk. The disks will be stored in a jukebox, and when a user requests material in the system, the appropriate disk will be retrieved, the requested page images stored on the magnetic disk buffer for use, and the optical disk returned to the jukebox so that it can be accessed by other users. If the user wants a copy of the material, he or she may use the convenience printer or may request an offline batch print from the high speed printer.

As of late 1984, all hardware and software components of the system were in place. The separate modules were undergoing exhaustive individual testing before being linked for full system testing. Initial indications are that the selected optical disk technology, which uses Thomson-CSF pregrooved disks with a capacity of 1GB per surface, is performing adequately. Four test disks have been created and there appear to be no problems in retrieving the stored data. (The disk manufacturer is, however, currently considering a change in disk production technology from plastic to glass substrate.)

Project descriptions published by the Library present a wide-ranging overview of the possible impact of optical digital disk technology on library and information services. A major interest is the potential of the optical digital disk as a secondary preservation format. Although the technology is so new that its long-term preservation qualities have not been tested, the projected disk life span of between 10 and 20 years offers long-term preservation potential. It is possible to monitor the quality of the data on a disk surface. When errors are detected, the digitally encoded data can be transferred onto a new disk with no loss of quality. This approach

focuses not on the preservation of the disk, but rather on the preservation of the original information stored on the disk. The information can be transferred without loss from an older optical disk onto a new one.

The medium also has potential for improving service to on-site users. Currently, users of the Library's collections must identify bibliographically the material they wish to use, submit call slips, and wait for the material to be delivered to the reading room in which they are working. During busy periods, delivery time can be as long as two hours. If the requested material is in use or is not on the shelf for some other reason, it is effectively lost for that user at that time. Where such material is on optical disk, it could be retrieved and displayed within a matter of seconds for viewing by several readers simultaneously.

The technology also offers more convenient access to library materials. If, for example, a reader wishes to use material from the general collections, current periodicals from the Serial and Government Publications Division, maps from the Geography and Map Division, and manuscripts from the Manuscript Division, under the present system he or she must go to four different reading rooms. In an optical disk document delivery system, manuscripts, maps, and music, as well as regular print material, could be accessed via the same terminal.

The medium has the potential of making a considerable impact on library space requirements. Optical digital disks store information at very high densities. For instance, one 8 x 10-1/2 inch book page occupies 54,000 square millimeters. The same page on 35mm microfilm occupies 150 square millimeters and, on 98-frame fiche, 70 square millimeters. On optical disk, the image of that same page occupies three to six square millimeters, depending on the nature of the information on the page.

As illustrated in the DEMAND system, the technology also allows for significant image enhancement. Background dirt, stains, and smudges can be eliminated on the scanned image so that the copy is clearer and more legible than the original.

Material chosen for use in the LC print project includes popular and scientific journals, four legal collections, manuscripts, sheet music, maps, and technical reports. One million images are to be scanned during the project. Commentators addressing the implications of the project point out that not all library materials are suited for storage and retrieval on optical disk--or any other mass storage medium. Readers cannot be expected to read hundreds of pages of small print from a display terminal, nor could the Library of Congress either afford enough display units to provide unlimited use for all its readers or handle the labor of scanning everything in the collections. Materials used mostly for reference, browsing, or reading in short segments are especially well suited for optical disk storage. Terminal sessions for these materials would tend to be brief, avoiding reader fatigue as well as long lines of other readers waiting their turn.

To address copyright and other issues of importance to the publishing, information, and library communities, the Library has established advisory groups to consider issues such as possible payment of fees, the role of the Government versus private industry in the development of systems based on the technology, and selection issues. The majority of publishers appear supportive of the pilot program. They have requested reassurance, however, that the Library does not intend to enter into a competitive publishing business and that it be sensitive to their concerns about copyright fees.

Use of materials in the test system will be monitored to provide information about how many times an image has been

displayed, printed locally, or printed in batch mode. This information may be used to develop and implement an accounting system at some future time.

The project has already offered opportunities for the development of standards that may be applicable throughout the information community. A temporary solution to the lack of a formal standard for the bibliographic description of individual serial issues has been devised using the ISSN concept. The body of each serial issue record used to control items in the system consists of the control number, document title, and date and issue information as found on the issue. The document control numbering scheme is modeled on the former Copyright Clearance Center Code, one of the proposals under consideration by an ANSI Subcommittee as a possible serials standard identifier code. This scheme uses the ISSN to identify the serial title, and adds a numeric expression of the chronology and enumeration to identify the specific volume and issue. For example, the document control number for Serials Review, Volume 8, Number 3, Fall 1982 would be:

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0098-7913/82-15-00/008-003
   ISSN   YR | DAY VOL ISSUE
             |
          MONTH OR QTR
          (15=FALL)
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Thorough testing of all aspects of the pilot is an integral part of the project. Among the issues to be specifically addressed are input work flow and procedures, time required to prepare documents, incidence of problems requiring special handling or rehandling, optimum spans of time for staff to perform each function, and overall estimates of the cost of transferring a document onto disk. User reactions to the system are to be determined using a series of questionnaires. Such aspects as ease of viewing, print quality, response time, material included, comfort of the user station, convenience, the effect of monochromatic image display, fees, instructions

on use, and so on, will be addressed. The results of the questionnaires will be used to determine future applications of disk technology for public use. Plans for staff training, documentation for the system, long-term retrievable requirements, signage and other public notice requirements, policy guidelines, and statistical requirements are also being developed.

The pilot program will also encompass a variety of experiments to determine procedures for dealing with the preservation of information on optical disks. This research will include performing quality assurance measurements on blank disks and written disks. The tracking of the quality of the digital information on the disks and specific physical and optical characteristics of the disks when they are first written and as they age is being undertaken by the Preservation Research and Testing Office. In addition, procedures will be developed to apply these measurement strategies to the daily practice of making optical disks and then to monitor the disks' long-term preservation quality. Storage conditions, handling procedures, details about data transfer, and coordinated lifetime measurements will be investigated.

In devising such a wide-ranging test of the optical digital disk technology, the Library of Congress project will return results which will be relevant for all disk-based applications, not only those of direct import to the library and information science communities.

OTHER PROJECTS

National Library of Medicine

In its Electronic Document Storage and Retrieval (EDSR) program, the Lister Hill Center of the National Library of Medicine is assembling a prototype system that electronically scans paper documents, processes the resulting signals for storage on magnetic and optical media and allows access to and retrieval of the stored image on both hardcopy and softcopy

devices. The program is designed to test techniques and components and to allow the evaluation of the usefulness of such a system in library information processing.

The project is designed to support a search of a standard bibliographic data base yielding a list of citations followed by rapid retrieval and display of images of the source documents of interest. Wherever possible, the system uses existing hardware components with in-house effort concentrated on the design of hardware interfaces and facilitating software.

The experiment is being undertaken using the National Library of Medicine's online catalog. The subject area "Neoplasms and the Child" has been chosen as the focus of the test. Approximately 1,000 pages from the relevant literature have been input to the EDSR system. These include title pages and tables of contents from monographs.

Most of the hardware used in the system is commercially available. The components include a page scanner, an image digitizer, a system controller, magnetic disks, search termials, high resolution display units, and printers. An optical disk storage device will be added to the system which currently uses magnetic disks for the storage of the digitized page images. A book scanner for handling the input of pages from bound volumes was developed in-house.

National Air and Space Museum

Work being undertaken at the National Air and Space Museum also seeks to utilize existing components. The focus of this effort is document storage and retrieval in an office environment.

The prototype system being assembled uses a DataCopy camera to digitize images at a resolution of 200 lines per inch--sufficient to support the application of optical charac-

ter recognition techniques to convert the stored images to ASCII coding at a later date. (Bell Northern is developing techniques to support the automatic conversion of such digitized image data to computer-readable ASCII form.)

A number of technologies have been combined for storing the digitized image data. A flexible optical disk being developed by McDonell Douglas Electronics has received particular attention. The medium apparently uses photographic techniques in the recording process and is expected to offer an archival life of 100 years. The product is not yet commercially available and in response to later inquiries, McDonnell Douglas was reluctant to release information in late 1984, citing the expected availability of product literature in January 1985.

The McDonnell Douglas technology appears to offer price/performance advantages over other optical storage approaches. The alternatives considered included the mastering of video-discs encoded with digital data and the use of optical digital disks from Storage Technology. Thomson-CSF technology was tried, but there were problems with the performance of the laser. It is thought that a McDonnell Douglas recorder/player will be available for $20,000 to $30,000 and that blank disks will cost $1.50. Recording is apparently undertaken on-site and the disks require no off-site processing. Data can be recorded interactively--there is no need to collect it on an intermediate storage medium before writing the disk. Separate disk players are expected to cost $500, but the cost per work-station could be as high as $7,000 when high resolution monitors and microcomputers are added. The disk players are said to read the data from the disk using an incandescent light bulb. The single-sided disks have a capacity of 100,000 black and white documents.

As of late 1984, the image data was being held on Winchester disks. An appropriate storage technology--possibly the McDonnell Douglas approach--was to be implemented as the next stage of the project.

Although undertaken as a small (2 person) back-room project, the system integration work being undertaken at Air and Space is wide-ranging. The technologies being tracked for possible implementation include automatic indexing based on the application of software under development for national security agencies and the optical character recognition processing of digitized images. Consideration is being given to patenting any operational system that results from the integration effort.

Public Archives of Canada

The Public Archives of Canada was an early user of videodisc, preparing a demonstration disc to test the application of the technology in archival storage of still and motion pictures, sound and text (using the approach now used by IITRI and described in chapter 2). More recently the Archives has been testing techniques for the digitizing of image data and the use of optical digital disks. The Archives expects to place an order with Geac--a computer manufacturer active in library automation--for delivery of a turnkey optical storage system using Thomson-CSF glass substrate disks and drives. The initial application will be storage of machine-readable data currently held on magnetic tape.

In the United States, Subcommittee C of the National Archives and Record Service's Advisory Committee on Preservation has recommended against the use of optical digital disks for the storage of machine-readable archives. In the letter of transmittal dated August 13, 1984, attached to its White Paper "Strategic Technology Considerations Relative to the Preservation and Storage of Human and Machine Readable Records," the Chairman of the Subcommittee noted that it had found:

"...that the proper interests of the National Archives and Record Service in the preservation of the information carried by machine readable records will not be served by reliance upon further investments in digital technology. Records deemed to be of archival value should be converted to a human readable form before accessioning. Only in this way can the availability and intelligibility of the information be guaranteed over the centuries."

The subcommittee's recommendation is based on a concern that, as machine-readable records are often usable only in the technology environment--hardware, software, and accompanying documentation--in which they are created, this environment would also have to be preserved for the data to be usable.

Disclosure

At the SLA meeting in New York in 1984, the Disclosure Information Group demonstrated LaserDisclosure, a prototype system for the electronic delivery of facsimile images of Securities and Exchange Commission filings. The company has been producing copies of SEC filings on microfiche and paper since 1967; the files grow by some 150,000 fiche a year, representing an enormous filing, organization and retrieval load. Although fiche are issued daily and subscribers receive them seven to ten days after the documents are received from the SEC, timeliness can be a problem given the volatility of the subject matter.

The new system, due to be offered to 29 major Disclosure subscribers in New York in early 1986, is designed to overcome such problems. Documents--in hard copy or microform--will be scanned and the digitized images will be stored on optical digital disk at the Disclosure facility. Users will dial into the system to access and retrieve required documents. The digital data representing the image of the piece will be transmitted from the Disclosure facility to high resolution terminals at the user's site. Because of the large amount of data required to store a document image, a rapid telecommunications channel capable of handling vast quantities of data is

essential to the success of the application. Disclosure has chosen to utilize fiber optics channels to achieve this data handling requirement. [The fact that New York City offers fiber optics communications is significant in the choice of initial LaserDisclosure sites.]

High speed laser printers attached to the users' terminals will allow the rapid on-site printing of documents for which hard-copies are required. The scanning, storage and printing technologies to be used in LaserDisclosure are similar to those used by the Library of Congress in its DEMAND card printing system, and sample hard copy outputs are of similar high quality.

Access to material published on fiche prior to the introduction of LaserDisclosure will also be facilitated by the new system which includes a digitizing microfiche scanner. This will be installed at the user's site and is used to convert fiche images, on demand, to digital format for printing on the laser printer. The copy quality achieved by this process is far higher than with regular fiche printing devices.

Disclosure intends to continue producing SEC materials on fiche as it is not foreseen that all customers will be able to justify the cost of the LaserDisclosure service. Although not yet finalized, it appears that the service will be available for $100,000 to $200,000 a year; a cost that is apparently not significantly different from the charges now paid by full subscribers to Disclosure products.

The system is being developed by Integrated Automation, the same company working with the Library of Congress on its print pilot project. Current expectations are that the system will be configured using optical disks developed jointly by Philips and Thomson-CSF. The high resolution terminal is

produced in California, and the laser printer contains components from several sources.

Although the system is not due to be operational before 1986, Disclosure's early announcement was prompted by the Securities and Exchange Commission's decision to implement an ASCII-based Electronic Data Gathering Analysis and Retrieval (EDGAR) system. The company's clients were concerned as to how Disclosure planned to handle this development and continue to provide service.

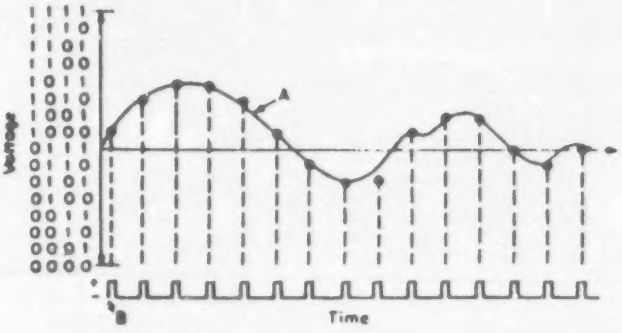
If implementation goes according to schedule, Disclosure plans to extend the LaserDisclosure service to other major cities as fiber optics links capable of handling the communications become available. Extension of service to Boston by mid-1986 appears possible.

APPENDIX: CONVERTING TEXT, GRAPHICS AND AUDIO TO DIGITAL FORM

DIGITIZING AUDIO DATA

The conversion of analog sound waveforms into digital form is used in the production of compact audio discs, in the provision of extensive sound over still capabilities for videodisc systems, and in office applications for the storage of voice messages.

The conversion of an analog audio signal to digital form is achieved by sampling the amplitude of the continuous analog audio signal A on a time basis B, yielding for each sampling point a discrete value represented by a dot on or near the analog curve.



Digital Encoding of an Analog Wave Form

Source: Electronic Engineers Handbook. Second edition. New York, NY: McGraw-Hill, 1982. p. 19-84

In this example the vertical scale is subdivided into 16 possible voltage levels. Each voltage value is represented by a different binary number or "word". The 16 values can be represented by a 4-bit word, shown on the left of the diagram. The first eight "words" of this analog sound wave can be read out either in parallel

1000, 1010, 1011, 1011, 1010, 1000, 0110, 0101, ...

on four channels, or in sequence

10001010101110111010100001100101...

on a single channel for transmission, recording and playback, and decoding into an approximation of the original wave train.

For faithful sound reproduction, it is generally agreed that sampling should be undertaken at a rate in excess of twice the highest significant frequency in the sampled wave. The upper frequency limit to be reproduced depends upon the application and ranges from 4 kHz for telephone systems to 20 kHz for master recordings of music. Corresponding sampling frequencies now in use are 8 kHz for telephone transmission and from 42 to 50 kHz in master recording of music. The degree to which digitization approximates the analog curve is determined by the number of digits chosen to represent the sampled data. Although speech-replication systems need only a 7-digit code (128 identifiable amplitude levels), the digital master recorders for music employ up to 16-digit codes (up to 65,536 identifiable levels) to obtain the required dynamic range. The choice for a particular application has obvious impact on the amount of digital data generated by the process.

Compaction techniques can be applied to compress the amount of digital data resulting from the conversion of audio data to digital form. Compaction is discussed in the section on image scanning.

CONVERTING TEXT AND GRAPHICS TO DIGITAL FORM

There are at least three ways in which the information on a page of paper or a frame of microform can be made available for storage in digital form. The form of digital output varies: the results of some processes are machine-searchable, and may be manipulated and searched in the same way as the data in a machine-readable data base; the output from other digital processing is not machine-searchable but is a "bit-map" which can be reassembled into a physical replica or facsimile of the original page.

The first method is the most familiar: the manual keying of the information content of a page into machine-readable ASCII coded data. The resulting data is machine-searchable

and can be printed out onto paper, but it cannot be reassembled into an exact physical copy or facsimile of the original page. While obviously applicable to text and tabular information, this method cannot be applied to illustrations. Manual keying is not discussed in detail in this report.

The second method--processing the information content of a page using optical character recognition (OCR) techniques--uses technology similar to that which forms the basis for the Kurzweil Reading Machine. Each alpha or numeric character is recognized and translated into the precise machine-readable ASCII code for that character. The method can be applied to text and simple tabular information but is not appropriate for handling illustrations or graphics. The resulting data has the same characteristics as data produced by keyboarding: it is machine-searchable, but cannot be reconstructed into a facsimile of the original.

The third method involves the image scanning technologies developed for use in telefacsimile equipment. In this process the objective is not to isolate and recognize distinct characters but merely to capture the pattern of the marks on the page, and to record that pattern in binary code. The output from the process is not machine-searchable, but can be reassembled to produce a facsimile of the original page. Text, graphics and illustrations can be handled in this way.

It is becoming feasible to combine image scanning and OCR techniques. When both processes are applied prior to data transmission or storage, the amount of data generated by image scanning can be considerably reduced.

A fourth method--the capture of document content in machine-readable form at the time that it is processed prior to publication--is not discussed in detail in this report. It yields machine-searchable data.

Optical Character Recognition

Optical character recognition provides an efficient and effective way of converting typed or printed material into machine-readable form. Sophisticated scanners are much faster than human keyboarding and often more accurate; some of the simpler scanners can achieve very rapid input rates. While the technology has developed to a stage where OCR can be applied to a range of fonts and is no longer limited to the familiar "awkward" OCR typefaces, applications in environments where a variety of unpredictable print styles may be encountered are limited even for those scanners which can store the characteristics of 10 or 15 different fonts.

Kurzweil Computer Products, a subsidiary of the Xerox Corporation, manufactures an omni-font optical scanner that can read a wide variety of type fonts. The Kurzweil 4000 Intelligent Scanning System creates a new set of digital character descriptions for each print set it scans. Conventional OCR scanners have the character descriptions for the selected font(s) installed at the factory. The Kurzweil approach gives the system great flexibility, but requires time to "train" the machine to identify the characters encountered in each job. Only the basic character shapes are actually installed in the unit; the variations for each print set are set up with the assistance of an operator. The unit will accept bound copy or single sheets; a printed work; a typescript; or a reasonable quality photocopy--including a photocopy made from a microform.

Two steps are involved in setting up the 4000 for a particular job: calibration and training. In calibration, the scanner searches the feeder surface for the first line of text, then automatically adjusts its recognition parameters to the size, width and curvature of characters on a line. The unit is programmed to recognize all serif and sans-serif fonts between 6 and 24 points. It displays an enlarged image of

each letter with its "best guess" as to the identification of the letter. The operator corrects or overrides wrong guesses, and the system incorporates these corrections into its memory. Once calibration is completed the system goes into training mode.

In training mode, the system presents the operator with a series of questions about the print type. These cover the nature of ambiguous characters--such as "1" and "1," "0" and "o"--the level of the black/white contrast, and the division of the text into paragraphs. The operator develops a "training set" geared to the particular text. The process covers both the characteristics of a font and typesetting information.

Training is progressive. As the operator defines the characteristics of the text, the scanner applies them in subsequent scanning and improves its ability to identify text accurately and add any required typesetting codes automatically. Thus it is "trained" to read a new text and "remembers" by storing a set of correspondences in a "training set" which may be used again when the same printed text type is submitted.

Once the scanner has been "trained," operator intervention is required only when the confidence indices stored in the system are exceeded--that is, when the system encounters a new unknown element or an element with poor print quality, such as run-on letters or partial letters.

The speed at which the Kurzweil 4000 will convert printed text to machine-readable form depends on the size of the characters used in the text, the number of varieties of characters and fonts, the quality of the print, and the page format. The minimum claim for the earlier model of the unit--the Kurzweil Data Entry Machine--was an entry speed of 30 cps (characters per second) with an error rate of 1 in 20,000 characters.

In testing earlier versions of the system on complex printed material such as reference works, bibliographies and encyclopedias--applications with multi-column page formats and text in a large variety of fonts, interspersed with graphics and illustrations--the throughput rate has often been disappointing. For example, the average throughput of the text of a major U.S. encyclopedia was only 27 characters per second. The machine did perform well on less complex monograph or typescript-like materials.

The system can be configured to incorporate text processing capabilities, and the ability to capture and retain underlining. A lexicon is available as an option. The English language lexicon contains some 33,000 words. The lexicon is applied during the machine training process to assist in character identification. Application of the lexicon during scanning further reduces the need for operator intervention. An "electronic tablet" feature gives the scanner the ability to bypass designated parts of a text.

The cost of the unit has decreased dramatically over the past several years. The base price for the Kurzweil 4000 is now $34,000.

This account has focused on one of the most sophisticated OCR machines. Much simpler devices are available from a number of manufacturers at lower prices. Regardless of the OCR unit employed, the output is the same--ASCII-coded, machine-readable and -searchable data which can be transferred to optical media using the techniques for data handling described throughout this report.

Image Scanning

Image scanning utilizes the technology found in telefacsimile machines. Pages of textual or graphic data are scanned using devices which sense the amount of light reflected from

(or, in the case of microfilm or microfiche, transmitted through) a very small zone or element of an image. The results of the scanning process are manipulated by a variety of techniques and output for storage or transmission.

Different scanning devices employ different techniques for scanning, sensing, and signal generation. Whatever the method used, a scanner focuses sequentially on tiny elements --pixels--of the page being copied. A sensing device converts the image patterns of the original into an equivalent electric signal, the intensity of which varies according to the amount of reflected light. Dark (text) areas of the copy absorb light, light (background) areas reflect it. The signal which represents the patterns of varying reflectivity from the source document may be processed in analog or digital form.

Analog devices output a continuously varying electrical signal which represents the scanned document as a steady stream of light, varying in intensity. This permits the capture of tonal variations other than black or white. The number of shades of gray--up to 16 with some devices--registered by a particular unit depends on the sensitivity of the scanning mechanism. For each picture element that is scanned a photocell produces an analogous electrical signal. A combination of these picture element signals creates a continuous electrical waveform. This waveform may be converted to digital form using the same techniques as are applied to the conversion of an analog sound wave to digital form.

Digital units monitor the light intensity of each picture element and determine whether to register that area of the copy as dark or light. Digital units with sophisticated scanners and electronic decision circuits can distinguish a range of values other than black and white, enabling the registration of gray scale. The decisions are recorded as a series of on/off electrical pulses rather than as a continuous graduated stream of electrical current.

Document enhancement features permit the manipulation of the degree of contrast between the tonal variations recognized by a scanner. Consider an input document containing six shades of gray between black and white, each shade supposedly representing an equal tonal stop between the base registers of white and black. Exposure to the sun might have caused that image to degrade to the point where all eight tones are accommodated within the span of the "lower" half of the continuum, with white registering as white, but black represented as only mid-gray. The application of document enhancement techniques to the output from the scanning process can allow the reproduction of the original, unfaded, tonal variations in copies of the document output from the scanned data. Contrast control may also be used to adjust image clarity.

Data from a digital scanning process may be encoded as one bit per pixel (a 1-bit binary word) if the image is in black and white with no significant gray scale values to be recorded. The unit determines whether a pixel does or does not contain data--whether it represents black or white space. Elements which contain data may be coded as binary "ones," those which do not contain data as binary "zeros."

The registration of tonal variation requires more complex encoding schemes as each pixel has to be judged against a range of potential information values. More information has to be recorded to depict a range of conditions more extensive than on/off or black/white. Accordingly, the digital representation of each pixel requires more bits, the number depending upon the number of gray scale conditions to be recorded. The allocation of four bits per pixel is sufficient to encode up to 16 levels of tonal variation. Assignment of an eight bit code to represent each pixel, while generating prohibitive data loads, would permit the encoding of 256 levels of tonal variation.

Similar increases in scanning and coding complexity enable the recording of color.

Data compression techniques are applied to the output of the scanning process.

The resolution at which an image is scanned has significant implications for both the clarity of the reconstructed image and the amount of digital data generated by the scanning process. Resolution is expressed in terms of the number of scan lines per inch (lpi) and is measured both horizontally and vertically.

The resolution of the scanning process is determined by the size of the pixel used. To achieve a horizontal resolution of 200 lines per inch and a vertical resolution of the same magnitude requires that each pixel cover a square 1/200th of an inch high by 1/200th of an inch wide. At this resolution, an 8-1/2 x 11 inch document is 1,728 pixels wide and 2200 pixels deep. requiring 3,801,600 pixels to "cover" its surface.

The greater the number of picture elements used in the scanning process, the sharper the transitions from light to dark areas will appear in the resulting image. The scanning and registration of tone shades or color require the use of very small pixels to achieve the necessary definition of detail.

The resolution required for the legible hardcopy reproduction of different type sizes has been the subject of considerable research over the years. Certain conclusions are now generally accepted. To ensure character legibility, each must be covered by ten scan lines in the horizontal plane. (The eye pays less attention to resolution in the vertical dimension.) Legibility at the level of a word rather than

a character can be achieved with half that scanning density.

Type size is traditionally expressed in points, one point being equal to one seventy-second of an inch. The actual height of a character is always smaller than the corresponding point height which expresses the height of the block on which metal type used to be mounted. The relationship of point size to typical character heights is shown below:

Point size	Typical range of character heights
6	1/32 to 3/64 inch
8	3/64 to 1/16 inch
10	1/16 to 3/32 inch
12	1/16 to 7/64 inch
14	5/64 to 1/8 inch
18	3/32 to 9/64 inch

Thus, if the average height of characters in six-point type is taken to be 3/64th of an inch, and the character must be scanned by ten scan lines, the scanning resolution required for legibility is 213 lines per inch; likewise, for eight-point type with an average character height of 1/16 of an inch, the scanning resolution required for character legibility is 160 lpi.

The common typewriter fonts--pica and elite--are approximately equal to 12- and 10-point typefaces, requiring scanning densities in the region of 100 lpi. Studies of the type sizes used in monograph and journal publishing suggest that in scientific and technical journals published in the United States, the median type size is ten points. In foreign scientific journals and monographs in the social sciences and humanities, type size ranges from eight to 14 points. Significant amounts of information are also printed in characters

smaller than 1/16 of an inch, with some text and footnotes being less than 1/32 of an inch, in height (point sizes ranging from four to eight.)

Experience in facsimile has shown that scanning resolutions of 200 lines per inch give fine print legibility and good appearance. However, at this resolution, it is still possible to detect differences between processed documents and the original. Scanners of higher resolution are appearing--400 lines per inch provides better resolution than typical office photocopiers. For specialized graphics applications, scanners capable of finer resolutions from 500 to 1500 lines per inch are available.

Once an image has been scanned at a particular resolution, that resolution can never be increased--except by rescanning. However, material scanned at a particular resolution can be output or displayed at a lower resolution.

There are a number of techniques whereby the amount of digital data generated by image scanning or the conversion of sound waves to digital form can be compressed. The following description focuses on the compaction of data from image scanning operations, but similar techniques can be applied to other forms of digital data.

A digital signal may be compressed by run-length coding, a process in which brief codes are assigned to repetitive sequences of white and black allowing the use of a simple short code to represent data which may otherwise consist of many more bits of information.

For example, the first seven pixels of a scan line may be represented as:

WWWBBBB

where W signifies white space and B indicates the presence of data. This signal could be encoded as:

reducing the number of characters from seven to four. Because the values always alternate, it is only necessary to identify the value of the first element, allowing for further compression of the signal to:

3W4

The data compression techniques applied in run length coding may be either one or two dimensional. A one dimensional system removes redundancy across the horizontal span of a scan, concentrating on the white and black areas associated with individual scan lines and characters. The modified Huffman technique--frequently used by facsimile technology--is an example of horizontal run length encoding. Two dimensional coding--such as the READ (relative element address designate) technique--also compresses data along the vertical line of the page, taking into account the space between lines of text and within given characters. Two dimensional compression results in an even more compact signal than one dimensional reduction.

The amount of data generated by scanning the image of a standard 8-1/2 x 11 inch page is dependent upon:

- o the resolution at which the image is scanned. The higher the resolution, the larger the number of pixels to be scanned.
- o the degree of tonal variation to be captured in the scanning process. The higher the number of variations to be recorded, the higher the number of bits assigned to recording the condition of each pixel.
- o the data compression techniques applied.
- o the density of the image on the page. The density of a normal, typed office document is much lower than a closely printed journal page with footnotes and complex diagrams. Data compression techniques applied in scanning and compaction have less impact when a very dense page is being processed. Densely packed images

also require higher resolutions for effective reproduction.

The digital scanning of a page generates significantly more data than would be required to represent the information in ASCII code by manual keying or the application of OCR techniques. An average typewritten document page of 60 lines with 64 characters per line may contain a maximum of 3,840 typographic characters. If the 3,840 typewritten characters on a page are encoded in ASCII code and 128 one-byte formatting statements are added, a total of 4KB--32,000 bits--of data result. With appropriate software this data can be manipulated and searched using the searching techniques applied to fulltext files. Again with the aid of appropriate software, the machine-readable information can be formatted and printed out in hardcopy. Only alpha-numeric data can be coded in this way, graphics and illustrations cannot be so treated.

If the same typewritten page is digitized at a resolution of 200 lines per inch and the results of the scanning process are coded using one bit per pixel, 3.8 million bits are generated. Using the average digital facsimile compression factor of 15, this can be reduced to 253,000 bits or some 32KB. The resulting data is not machine-searchable because it is a digitized representation of a graphic image; however, the image can be reassembled on a high resolution monitor or a printer to form an exact replica or facsimile of the original page. This method can be applied to any image data: alpha-numeric characters, graphics, photographs, etc. If the image is to be coded so as to reproduce gray scale or colors, the number of bits required to represent each pixel is much higher.

OCR and Scanning in Combination

Even with sophisticated equipment many documents cannot be converted using OCR techniques. In some cases, this is due

to the poor quality of the original document. The application of image scanning and enhancement techniques can sometimes restore the document image to such an extent that it can then be handled by OCR technology. In other situations, the text part of a page can be converted using OCR, with graphics, tables, and illustrations being processed by image scanning.

When the reproduction of an exact visual facsimile of a document is not of major importance, the application of such a combined approach has advantages, because the ASCII coded data is both machine searchable and more compact. A number of companies are developing document handling systems which utilize both techniques.

These developments also have significance for conversions which utilize only image scanning technology.

Legibility for display or reproduction has been the major determining factor in the choice of the resolution at which an image is scanned. In many situations, this choice is determined by the initial application for which scanning is undertaken. With the emergence of technologies which appear to make long-term storage of digitized image data economically feasible, system designers need to address possible future applications. One such application may be the later processing of digitized image data by OCR techniques using more sophisticated procedures than are available at the time the material is scanned. Successful implementation may well require the manipulation of an image scanned at a higher resolution than that required by the display and output technologies extant at the time of the original digitization. As noted previously, the resolution of a scanned image cannot be increased except by re-scanning.